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Minimum Material in a Trussed Girder. (*A Thesis.*) By WILLIAM BOUTON, (University of Michigan.)

I propose to find the inclination of the braces (or ties), and the relation between the length and depth of a truss with horizontal chords, so as to demand the least amount of material in the construction, when the transverse section of the several parts are made proportional to the strains to which they are subjected.

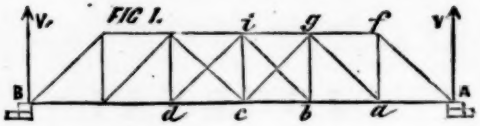
An exact analytical solution, I consider, from the nature of the case, impossible; but I desire to make an exact solution upon the following hypotheses, which may be more or less nearly realized in practice:

1st. Assume that the weight of the bridge is a uniform permanent load.

2d. Consider the surcharge—or moving load—as uniform as far as it extends.

3d. Assume that the joints at the ends of the braces or ties are perfectly flexible.

These assumed, and I can use the formulas which have been developed in the course of lectures on constructions, and which have been reproduced in this *Journal* by Professor Wood in his articles on "The General Problem of Trussed Girders," to which I shall hereafter refer. I will first consider the panel system, in which the inclined pieces are braces, and the vertical ones ties; in other words, I will consider a Howe's truss,—letting the load be on the lower chord.



Notation.

Let L = A B = the span,
D = $a f$ = the depth,
l = A a = $a b$ = $b c$ = the length of each bay,
N = number of bays, $\therefore l = \text{L} \div \text{N}$,
W_1 = the weight of the frame,
$w_1 = \text{W}_1 \div \text{N}$ = the weight of one panel,
p = the weight of the surcharge on one panel,
r = the weight of the surcharge per foot of length,

$$c = \frac{w_1}{p}, \text{ and } w_1 = \frac{c r \text{L}}{\text{N}}, p = \frac{r \text{L}}{\text{N}},$$

$$\therefore p + w_1 = (1 + c)\frac{r \text{L}}{\text{N}}, \quad . \quad . \quad (1.)$$

W = the total load = $(p + w_1)$ N,
θ = $g a f$ the inclination of a brace.

We have

$$\text{D} = \frac{l}{\tan \theta} = \frac{\text{L}}{\text{N} \tan \theta}, \quad . \quad . \quad (2.)$$

The length of a brace = D sec θ = $\dfrac{\text{L} \sec \theta}{\text{N} \tan \theta}$, . . (3.)

We will take up the problem by parts, and suppose, first, that the braces only are varied in size, and that the load is uniform over the whole length.

The strain on the nth brace is, (see the second of equations (45) p. 381, vol. xlviii,) $\frac{1}{2}$ (N—$2n$ + 1) $(p + w_1)$ sec θ, . . (4.)

By making $n = \frac{1}{2}$N in the 3d of the same equations, we find for the strain at the middle of the lower chord,

$$\frac{1}{8}\frac{\text{N}^2 l (p + w_1)}{\text{D}} = \frac{\text{W L}}{8\text{D}} = \frac{\text{W N}}{8}, \quad . \quad . \quad (5,)$$

and; by the hypothesis, the chord is to be made large enough throughout to resist this strain.

Making sec θ = 1 in (4), and we have

$$\frac{1}{2}(\text{N}—2n + 1)(p + w_1), \quad . \quad . \quad (6,)$$

for the strain on the nth vertical tie; but as they are to be of uniform size, they must all be as large as the first one, the strain on which is found by making n = 1 in (6). Hence the strain is

$$\frac{1}{2}(\text{N}—1)(p + w_1), \quad . \quad . \quad (7.)$$

Let K = the section of a brace,
S = the strain on a unit of section.

Hence (4) and (1) give

$$K = \frac{(N-2n+1)(1+c)}{s} \frac{r L}{2N} \sec \theta, \quad . \quad (8.)$$

In (8) make $n = 1, 2, 3,$ &c., ... to $\frac{1}{2}N$, and we shall form a series, the successive terms of which give the sections of the braces in their order. Summing the series, and we have for the total sections of the braces on half the bridge,

$$\Sigma K = \frac{N(1+c) r L}{8s} \sec \theta,$$

which, multiplied by the length of a brace, equation (3), gives for the volume of half the braces,

$$\frac{(1+c) r L^2}{8s}, \frac{1}{\cos \theta \sin \theta}, \quad . \quad . \quad (9,)$$

which is a minimum, for $\theta = 45°$. Hence, the minimum amount of material in the braces is

$$\frac{(1+c) r L^2}{2s} = \frac{p + w_t}{2s} = \frac{NL}{N} \quad . \quad (10.)$$

This shows that the total amount of material in the braces is the same as if the truss were a king-post with braces inclined at an angle of 45 degrees. The aggregate length of the ties will be the same whether the truss be composed of two or many braces; hence, equation (7) shows that the amount of material in the truss is least when N is least, or equal 2; hence the king-post truss requires *less* material for the ties and braces. Equation (5) shows that the strain on the chord varies with N; hence, the section of the chord is least in the king-post truss. When the inclination of the braces is varied, we shall still find an advantage in the king-post truss, but not as great as in the present case.

Next, *suppose that both the ties and braces are proportioned according to the strains to which they are subjected*, the load being uniform throughout.

By summing the series found by equation (6), and multiplying by the length of a tie, equation (2), we find for the volume of half the ties,

$$\frac{(1+c) r L^2}{8s}, \frac{1}{\tan \theta} \quad . \quad . \quad (11.)$$

Twice the sum of (9) and (11) gives the total volume of the ties and braces, which is

$$\frac{(1+c) r L^2}{4s} \left(\frac{1}{\cos \theta \sin \theta} + \frac{1}{\tan \theta} \right) \quad . \quad (12,)$$

which is a minimum for $\theta = 54° 45'$.

In the following table, the second column shows the relative amount of material in the braces only, for different inclinations; and the fourth column shows the relative amount in both ties and braces:

θ	$\frac{1}{\cos\theta \sin\theta}$	θ	$\frac{1}{\cos\theta \sin\theta} + \frac{1}{\tan\theta}$
45°	100·00	54° 45′	100·
40° or 50°	101·50	50°	101·5
35° or 55°	106·40	45°	106·4
30° or 60°	115·50	40°	113·7
25° or 65°	130·55	35°	125·7
20° or 70°	195·85	30°	142·9
15° or 75°	200·00	25°	168·1
10° or 80°	368·09	20°	207·1
5° or 85°	515·00	10°	407·3
0° or 90°	∞		
		60°	102·1
		65°	108·8

If we make the strains those due to a moving load, the braces (in the form of counter braces) will pass beyond the centre, and the *coefficient* of $\frac{1}{\tan\theta}$ will be less than that of $\frac{1}{\cos\theta \sin\theta}$; hence, will reduce the value of θ for the function a minimum toward 45°, a limit it can never reach. Indeed, it cannot reach 48°; for using the first two terms of equation (20) and make $w_1 = 0$, and $n_1 = N-1$, and solve for a minimum, and we find

$$(N^2-1)\tan^2\theta = \frac{31}{24}N^2 - \frac{28}{24}.$$

If N be very large, we have approximately

$$\tan^2\theta = \frac{31}{24} \therefore \theta = 48° 40',$$

which is the limiting value, but the practical value is nearer 54°.

General Problem.

The amount of material in the chords diminishes as the depth of the truss increases—N and L being constant—but this diminishes θ, hence increases the material in the ties and braces when θ is less than 54° 45′. Hence, there must be some value of θ which will give the amount of material required for *all* the parts a minimum.

When the load is uniform throughout and permanent, we know that no counter braces are necessary, and that all the braces incline towards the centre. But the surcharge which moves on or off is uniform over only a portion of the length, and the most unfavorable case is when it extends from one end of the bridge to the point considered. This case necessitates counter-braces. To find the number of braces which, in this case, must incline from either end, we place the second of (46) page 381, vol. xlviii, equal zero and solve for n. Call the rational value n_0, and we have

$$n_0 = N\frac{w}{p} + N + \tfrac{1}{2} - \sqrt{N^2\left(\frac{w^2}{p^2} + \frac{w}{p}\right) + \tfrac{1}{4}}, \quad . \quad (13.)$$

Then will the *number* of braces required be the integer part of n_0; or, if n_0 is an integer, it will be n_0—1. Call it n_1.

From the second of (46) above referred to, we have for the section of the nth brace,

$$\kappa = \left[(\text{N}-n)(\text{N}-n+1)p + (\text{N}-2n+1)\,\text{N}\,w_1 \right] \frac{\sec\theta}{2\,\text{S}\,\text{N}},$$

which, multiplied by the length, equation (3), gives for the volume of the nth brace,

$$\left[(\text{N}-n)(\text{N}-n+1)p + (\text{N}-2n+1)\,\text{N}\,w_1 \right] \frac{\text{L}}{2\text{S}\,\text{N}^2 \sin\theta\cos\theta} \quad (14.)$$

To find the volume of half the braces, form a series by making $\text{N} = 1$, 2, 3, &c., to n_1, and sum the series. Two series will be formed, one the coefficients of p; the other of w_1.

1. The coefficient of p.

By the method of the orders of differences, the sum of the series,

$$\text{S} = n\,a + \frac{n(n-1)}{2} d_1 + \frac{n(n-1)(n-2)}{2\cdot 3} d_2 + \&c.,$$

in which n = the number of terms,

a = the first term,

d_1, d_2, &c., = the first terms of the several orders of differences.

The terms of the series are

	N (N—1),	(N—1),	(N—2),	(N—2),	(N—3),	(N—3),	(N—4).
1st dif.	—2N + 2		—2N + 4		—2n + 6.		
2d dif.		+ 2		+ 2		+ 2.	
3d dif.			0		0.		

Substituting in the formula, and we have

$$\left[n_1\,\text{N}\,(\text{N}-n_1) + \tfrac{1}{3} n_1 (n_1^2 - 1 \right] \text{to be multiplied by } \frac{p\,\text{L}}{2\text{S}\,\text{N}^2 \sin\theta\cos\theta}.$$

2. Coefficient of w_1.

This becomes negative when we pass the centre, and each term cancels a corresponding one before we arrive at the centre; hence we need sum only from $n = 1$ to $n = \text{N}-n_1$.

The terms of these series are

	N (N—1)		N (N—3)		N (N—5)		N (N—7).
1st dif.		—2N		—2N		—2N.	
2d dif.			0		0,		

and the sum for $(\text{N}-n_1)$ terms is

$$n_1\,\text{N}\,(\text{N}-n_1) \text{ which is to be multiplied by } \frac{\text{N}\,w_1\,\text{L}}{2\text{S}\,\text{N}^2 \sin\theta\cos\theta}.$$

Adding the results, and using equation (1), and we have for *the total volume in half the braces*,

$$\left[\text{N}\,n_1(\text{N}-n_1)(1+c) + \tfrac{1}{3} n_1 (n_1^2 - 1) \right] \frac{r\,\text{L}^2}{2\text{S}\,\text{N}^3} \frac{1}{\sin\theta\cos\theta} \quad (15.)$$

Material in the Vertical Bars.

The equation for the strain is the same as for the braces, except that sec $\theta = 1$. The length is $\frac{L}{N \tan \theta}$. It will make a difference, whether N be odd or even. If N be odd, there will be $\frac{1}{2}(N-1)$ ties in half the bridge; and hence, $\frac{1}{2}(N-1)$ terms in the series. Hence the volume is

$$\left[\tfrac{1}{4} N (N^2-1)(1+c) + \tfrac{1}{6}(N-1)\left(\tfrac{1}{4}(N-1)^2-1\right)\right] \frac{r L^2}{2s N^3}, \frac{1}{\tan \theta}.* \quad (16.)$$

If N be even, there will be a middle tie, and after summing the series for $n_1 = \frac{1}{2}N$ terms, we must deduct one-half the volume of the middle tie. The volume of the middle tie is found by making $n = \frac{1}{2}N$, and sec $\theta = 1$ in the first term of (14), and using tan θ for $\frac{1}{\sin} \theta$. Hence the half volume is

$$\tfrac{1}{8} N (N+2) \frac{r L^2}{2s N^3} \frac{1}{\tan \theta}.$$

Summing $\frac{1}{2}N$ terms of the series, and deducting the preceding expression, and we have for the volume of one-half the ties,

$$\left[\tfrac{1}{4}N^3(1+c) + \tfrac{1}{6}N(\tfrac{1}{4}N^2-1) - \tfrac{1}{8}N(N+2)\right] \frac{rL^2}{2sN}, \frac{1}{\tan \theta} \quad (17.)$$

Material in the Chords.

The equation of the strain is (see the third of (45), page 381, vol. xlviii),

$$\tfrac{1}{2}(N-n)\, n\, (p + w_1) \tan \theta, \quad (18.)$$

For the half span the limits for n are, when N is even, $n = 1$ to $n = \frac{1}{2}(N-2)$ in the upper chord, and $n = \frac{1}{2}N$ in the lower. If N is odd, the limits are $n = 1$ to $n = \frac{1}{2}(N-1)$ in both chords, by omitting half the central bay in the lower, and including it in the upper chord, since their sections are the same. In either case the summation will be

$$\tfrac{1}{6} N (N^2-1)(1+c) \frac{r L^2}{2s N^2} \quad . \quad . \quad (19.)$$

Adding (15), (16), or (17) as the case may be, and (19), and we have for half the volume of the truss,

$$\left\{ \begin{array}{l} \left[N n_1 (N-n_1)(1+c) + \tfrac{1}{3} n_1 (n_1^2-1) \right] \\ + \left\{ \begin{array}{l} (\text{for } n \text{ odd})\ \tfrac{1}{4} N (N^2-1)(1+c) + \tfrac{1}{6}(N-1) \\ (\text{for } n \text{ even})\ \tfrac{1}{4} N^3 (1+c) + \tfrac{1}{6} N (\tfrac{1}{4} N^2 - 1) \end{array} \right\} \\ + \tfrac{1}{6} N^2 (N^2-1)(1+c) \tan \theta \end{array} \right\}$$

$$\left\{ \begin{array}{l} \dfrac{1}{\cos \theta \sin \theta} \\ \left\{ \begin{array}{l} \left(\tfrac{1}{4}(N-1)^2-1\right) \\ -\tfrac{1}{8} N (N+2)(1+c) \end{array} \right\} \dfrac{1}{\tan \theta} \end{array} \right\} \frac{r L^2}{2s N^3} \quad . \quad (20.)$$

* We have made no distinction between the resistance to tension and compression.

which is to be a minimum.

$$\therefore \left\{ \begin{array}{l} \left[\mathrm{N}\, n_1(\mathrm{N}-n_1)(1+c) + \tfrac{1}{3} n_1(n_1^2-1) \right] \\ -\left\{ \begin{array}{l} (n \text{ odd})\ \tfrac{1}{4}\,\mathrm{N}\,(\mathrm{N}^2-1)(1+c) + \tfrac{1}{6}(\mathrm{N}-1) \\ (n \text{ even})\ \tfrac{1}{4}\,\mathrm{N}^3(1+c) + \tfrac{1}{6}\,\mathrm{N}\,(\tfrac{1}{4}\,\mathrm{N}^2-1) \end{array} \right\} \\ \quad + \tfrac{1}{6}\,\mathrm{N}^2\,(\mathrm{N}^2-1)(1+c)\tan^2\theta \end{array} \right\}$$

$$\left\{ \begin{array}{l} (\tan^2\theta - 1) \\ \left\{ \begin{array}{l} \left(\tfrac{1}{4}(\mathrm{N}-1)^2-1\right) \\ -\tfrac{1}{8}\,\mathrm{N}\,(\mathrm{N}+2)(1+c) \end{array} \right\} \end{array} \right\} = 0, \qquad . \quad . \quad (21).$$

We see that the inclination is dependent upon the number of bays. To solve (21) assume N and c, and find n_1 by means of (13), and then we may find θ. In this way the following table has been computed.

TABLE *showing the inclination of the braces and the ratio of the length to the depth of a* HOWE'S TRUSS, *for a minimum amount of material, load on the lower chord:*

Value of N.	Uniform and permanent load. $p=0$ and $c=\infty$		$p=w_1$. ∴ $c=1$		$p=2w_1$. ∴ $c=\frac{1}{2}$			$w=0$. ∴ $c=0$	
	θ	$\frac{L}{D}$	θ	$\frac{L}{D}$	θ	$\frac{L}{D}$	Rel. value of $\frac{r\,L^2}{8}$ Eq. (20.)	θ	$\frac{L}{D}$
	° ′		° ′		° ′			° ′	
2	40 53	1·73	40 53	1·73	40 53	1·73	100	40 53	1·73
3	39 14	2·45	39 36	2·48	39 43	2·49	135	39 55	2·51
4	35 47	2·88	36 25	2·95	36 35	2·96		37 23	3·05
5	34 12	3·40	34 51	3·48	35 5	3·51		35 39	3·59
6	31 51	3·72	32 29	3·81	32 30	3 82		33 21	3·95
7	30 26	4·11	31 28	4·28	31 46	4·34		32 28	4·45
8	29 1	4·46	29 48	4·58	30 13	4·66	217	31 7	4·82
9	28 7	4·81	28 54	4·97	29 11	5·03		30 0	5·20
10	26 48	5·05	27 41	5·24	27 48	5·27		28 6	5·34
12	25 2	5·60	25 54	5·82	26 13	5·91		27 28	6·23
15	23 5	6·39	23 52	6·64	24 10	6·73		25 0	6·99
20	20 31	7·49	21 21	7·81	21 39	7·93	274	22 32	8·36
25	18 36	8·41	18 41	8·45	18 57	8·58		20 22	9·23
30	17 21	9·37	17 51	9·66	18 8	9·84		18 56	10·30
40	15 23	11·00	15 40	11·22	15 54	13·39		16 41	12·00
50	13 34	12·87	14 7	12·57	14 23	18·52	506	15 3	13·44
60	12 26	13·23						13 49	14·80

For $p = 2w_1$, I have added a third column of the relative value of the coefficients of $\frac{r\,L^3}{s}$ in equation (20). By this it appears that to support a *moving* surcharge, r L, plus a *uniform permanent* load $\frac{1}{2}\,r$ L, will require 5·06 times the material when the span is divided into fifty bays that it would if divided into two.

Although we find that the material does not increase with the number of bays so fast as it would if θ remained constant, still the increase is so great as to forbid our increasing N until there is no danger of rupture by flexure in the braces. But N must be increased until there is no danger of breaking in the loaded chord from transverse strain.

Let P be the greatest concentrated load which can come on any bay *e.g.*, on the driving wheels of a locomotive, $\therefore \frac{1}{4}\,Pl = \frac{1}{6}\,R\,bd^2$, but $bd = K \therefore K = \frac{3}{2}\frac{Pl}{Rb}$, which section must be less than that required to satisfy the formula $\frac{1}{2}(N-n)\,n\,(p + w_1)\,\text{tang}\,\theta = S\,K$. See equation (18.) This may be effected by making l, the length of the bay, small, or making d larger in proportion to b throughout the span. On the whole, I think it would be better to increase the section of the loaded chord so as to prevent danger from transverse strain, and not alter the disposition of the other parts, for such an alteration would increase the material in all the other parts, to avoid a danger which only requires the increase of one part.

Triangular Systems.

When the load is on the upper chord we find from equations (43) and (44), page 379, vol. xlviii, that

$$\left[(N-n)^2 p + (N^2-2nN)\,w_1\right]\frac{\sec\theta}{2N} = \text{the maximum strain on the pair of braces at the end of the } n\text{th bay.}$$

$(N-n)\,n\,(p + w_1)\,\tan\theta = $ strain on nth bay of upper chord.

$$\left[N\left(n-\tfrac{1}{2}\right)-(n-1)\,n\right](p + w_1)\tan\theta = \text{strain on } n\text{th bay of lower chord.}$$

Sum these equations for all integral values of n from the end to the centre of the truss.

1°. For the braces WHEN N IS EVEN and the first bar is a brace,

$n = 0$ to $\frac{1}{2}(N-2)$ for the main braces,
$n = 1$ to $\frac{1}{2}\,N$ for the ties.

Expanding the equation for the braces and ties with these limits, and we get for the total section of half the braces and ties when N is even,

$$\Sigma K = \frac{7\,N^3 p + 6\,N^3 w_1 + 2\,N\,p}{12}\cdot\frac{\sec\theta}{2\,N\,S}$$

The length of a brace is $\frac{L\,\sec\theta}{2\,N\,\tan\theta}$; hence,

Volume of half the braces and ties,

$$= \frac{(7+6c)\,N^2+12}{4} \cdot \frac{r\,L^2}{12\,N^2\,S} \cdot \frac{1}{\cos\theta \sin\theta}$$

WHEN N IS ODD.

The limits for the main braces are, $n=0$ and $n=\frac{1}{2}(N-1)$.
for the ties $n=1$ and $n=\frac{1}{2}(N-1)$.

$$\therefore \text{the volume} = \frac{(7+6c)\,N^2+5+6c}{4} \cdot \frac{r\,L^2}{12\,N^2 S} \cdot \frac{1}{\cos\theta \sin\theta}$$

The Chords.

For N *even* the limits are $n=1$ and $n=\frac{1}{2}N$, by subtracting $\frac{1}{2}(N-\frac{1}{2}N)\frac{1}{2}N=\frac{1}{8}N^2$ for half the central bay in the upper chord.

$$\therefore \text{the volume} = (2N^3+N)(1+c)\frac{r\,L^2}{2N^2 S}\tan\theta.$$

For N *odd*, the limits are $n=1$ and $n=\frac{1}{2}(N-1)$ for the upper chord, and $n=1$ and $n=\frac{1}{2}(N+1)$ for the lower chord, minus half the central bay of the lower chord, viz: $\frac{1}{8}(N+1)$,

$\therefore$ volume $= (2N^3+N)(1+c)\frac{r\,L^2}{2S\,N^2}\tan\theta$, the same result as before.

Hence the total material in half the truss is

$$\left[\begin{cases} \frac{1}{4}\left((7+6c)\,N^2+2\right) \text{(for N even)} \\ \frac{1}{4}\left((7+6c)\,N^2+5+6c\right) \text{for N odd)} \end{cases}\right\} \frac{1}{\cos\theta \sin\theta} + (2N^3+N)(1+c)\tan\theta \Bigg] \frac{r\,L^2}{12\,S\,N^2}, \quad . \quad . \quad . \quad (22.)$$

which for a minimum gives

$$\begin{matrix} N \text{ even,} \\ N \text{ odd,} \end{matrix} \begin{cases} (7+6c)N+2 \\ (7+6c)\,N^2+5+6c \end{cases} (\tan^2\theta - 1) + (8N^3+4N)(1+c)\tan^2\theta = 0, \quad . \quad . \quad . \quad (23.)$$

It will be observed that I have considered the compressive and tensive resistances equal; otherwise the final equation would be slightly modified.

From equation (23) and the equation $\frac{L}{2N\tan\theta}=D$, I have made the following table:

Values of		θ	$\frac{L}{D}$
N	c		
		° ′	
6	$\frac{1}{2}$	19 11	4·17
9	$\frac{1}{2}$	16 14	5·03
40	$\frac{1}{2}$	8 8	11·43
50	0	7 28	13·11
12	0	14 37	6·25

I have chosen these values of N and c wholly at random; and it will be perceived that the ratio of L to D corresponds very nearly with the results for the panel system for the same value of N.

Approximation.

When N is large we may drop all the terms below N^2, and we shall have

$$(7 + 6c)(\tan^2\theta - 1) + 8N(1 + c)\tan^2\theta = 0. \qquad (24.)$$

In this, when $N = 9$ and $c = \frac{1}{2}$, the formula differs from the exact one, less than a minute in the value of θ. For larger values of N the difference will be inappreciable, as shown from the following table:

N=	c=	θ	$\frac{L}{D}$
		° ′	
12	0	14 37	6·25
40	$\frac{1}{2}$	8 8	11·43
50	0	7 28	13·11

This approximation may be made for the panel system to get the relation of L to D, since the relation is nearly the same in both systems. The peculiar value of the factor n_1 in the panel system forbade such an approximation in the general equation.

In like manner, we may determine the relation between the length and depth, and the proper inclination of the braces, in any truss in which the strains may be expressed by a continuous function.

The relation of p to w_1 in any practical case cannot be accurately known beforehand, but as all possible inclinations are found from the equation between that resulting when $p = 0$, and that when $w_1 = 0$, and as these values do not differ more than two degrees, a very close approximation may be very readily arrived at. The function varies slowly about its minimum so that a *degree* even will make little difference.

We should diminish the number of bays as much as possible consistently with the liability to rupture by transverse strains and flexure by too great length, and having fixed upon N, determine the relation of p to w_1 as nearly as possible, and then make $\frac{L}{D}$ correspond to the equation for minimum material.

It will be seen that the results which I have obtained for the minimum material, all approximate the value of θ required for the minimum depression of a single triangle composed of bars of uniform section, and sustaining a weight at its apex; that is, they are nearer it, (30°,) than they would be if inclined so that the material in the ties and braces above should be a minimum. Let me suggest to the patient reader that a triangle sustaining compression in both its braces, is not in the same condition as one sustaining compression in one and extension in the other, as in the case of all bridges. Let me also inquire what effect the compression in the upper chord has upon the rigidity of the whole? Is 30° then an approximation to the inclination for the greatest rigidity in a trussed girder?

Multiple Systems or Lattice Trusses.

In adhering to the simple systems I have shown that the minimum material in the *whole* is obtained by increasing that in the braces above the minimum amount, and so increasing the depth of the truss. Cannot both advantages be combined by retaining the depth of the truss while increasing the inclination of the braces by passing them across two or more panels? This course, while it increases the length of the braces, so much reduces their section as to require less material if we neglect flexure. But both these modifications leave them much more liable to flexure; moreover, the strains cannot be rigidly analyzed, so that much more will have to be added for safety, as well as to prevent the increased liability to flexure, so that we should have little gain. This criticism does not apply to Whipple's truss, or to any other in which the inclined bars are ties. In them I think the multiple system must be advantageous, although it cannot be rigidly calculated.

On Uniform Stress in Girder Work; illustrated by reference to two bridges recently built. By Mr. CALLCOTT REILLY, Assoc. Inst. Civ. Eng.

From Newton's London Journal of Arts, June, 1865.

This communication was suggested by a previous discussion at the Institution, when Mr. Phipps (M. Inst., C.E.,) condemned the trough-shaped section commonly adopted for the top and bottom members of truss girders, because the intensity per square unit of the stress upon any vertical cross section was necessarily variable when the connexion of the vertical web with the trough was made in the usual manner. In the construction of the iron work of the two bridges under consideration, attention was invited chiefly to those details which were de-

signed with the object of carrying out as nearly as possible in every part of the girders the condition of uniform stress.

After alluding to the distinction drawn by Prof. Rankine between the words "strain" and "stress," and to his definition of "uniform stress," in which the "centre of stress" or "centre of pressure" must be coincident with the centre of gravity of the surface of action, and of "uniformly varying stress" when the centre of gravity deviated from the "centre of stress" in a certain known direction, it was remarked that the failure of any member of a girder would begin where the resistance to strain was really the least, that was, where the intensity of the stress was greatest; from which it followed that the opinion which upheld as right in principle the trough-shaped section, as applied in the usual manner, must be a mistake. And, moreover, every form of section of any member of a girder, or other framework, which did not admit of the approximate coincidence of the centre of stress with the centre of gravity, was liable in degree to the same objection.

The two bridges illustrated different conditions of loading; one carrying the platform on the top, the other having the platform between the main girders near the bottom. Both were of wrought iron, and both exhibited an economy of material in the main girders that, so far as the author was aware, was not common at least in this country. In order to determine the causes of this economy, a comparison was made with two other forms of truss more generally adopted. In one bridge over the river Desmochado, on the line of the Central Argentine Railway, the pair of trusses, 93 feet 4 inches span between the centres of bearings, was designed to carry, in addition to the fixed load, a moving railway load of 1 ton per foot of span for a single line of way, with a maximum intensity of stress of 5 tons per square inch of tension, and of $3\frac{1}{2}$ tons per square inch of compression; and the total weight of wrought iron in the framework of the pair of trusses was 18 tons. The cast iron saddles rivetted on at the ends weighed 9 cwt.; if these were included the weight of iron, both wrought and cast, in the pair of trusses was under 4 cwt. per lineal foot of span.

The other bridge, over the Wey and Arun Canal, on the Horsham and Guilford Railway, was 80 feet span between the centres of bearings; it was designed to carry, in addition to the fixed load, a moving load of 1·875 ton per foot of single line of way, at the same maximum intensity of stress as in the other case; and the total weight of wrought iron in the pair of trusses was 20 tons 18 cwt. The cast iron saddles weighed $5\frac{1}{2}$ cwt. each; bringing up the weight of both wrought and cast iron in the pair of trusses to $5\frac{1}{2}$ cwt. per lineal foot of span. This weight was greater than in the first bridge, although the span was less; but the intensity of the moving load was $87\frac{1}{2}$ per cent. greater, and the roadway lying between the trusses instead of on the top, its weight was necessarily much greater. The cross girders were also heavier, each being adapted to support, separately, the heaviest load that could be brought on by a driving axle weighted with 16 tons; the moving load thus brought upon each cross girder, and to which its

strength was proportioned, was 18 tons, equal to $2\frac{1}{4}$ tons per foot of span of bridge.

The particular form of truss chosen for these two bridges was that extensively known in the United States as the Murphy-Whipple truss. Each of these trusses was minutely compared, according to the plan adopted on a previous occasion by Mr. Bramwell (M. Inst. C.E.), with two equivalent trusses of the types generally used in this country, viz: the Warren truss, with bars making an angle of 63° 26′ with the horizon, and the simple diagonal truss with two sets of triangles, the bars crossing each other at the angle of 45°, the various circumstances of ratio of depth to span, which was as 1 to 10, and of application and distribution of load, and consequently the number and position of the loaded joints, being common to the three trusses.

The details of the comparison were fully given in the paper, and the proportionate results arrived at in the two cases were exhibited in the following tables, relating to the trusses of the two bridges contrasted respectively with the other equivalent trusses:

BRIDGE No. I, WITH LOAD ON THE TOP.

	No. 1. Murphy-Whipple Truss.	No. 1 A. Warren Truss.	No. 1 B. Diagonal Truss.
	Units.	Units.	Units.
Theoretical weight, ...	250	237·5	227
Weight of transverse stiffening to struts, ...	17·4	29·2	42·2
Excess of practicable minimum over theoretical minimum, ...	6·18	11·5	31·6
Total weight, exclusive of joints and packings, . .	273·58	278·2	300·8

From this it appeared that the least practicable weight of No. 1 truss was less than that of No. 1 A by only 1·7 per cent. It might, therefore, be said that practically the two trusses were equal in point of economy; and that there could be no motive for preferring one to the other, except such as might arise from considerations of workshop convenience and facility of construction. The advantage in point of economy of weight of No. 1 over No. 1 B was more decided, being 10 per cent.,—sufficient, it was admitted, speaking generally and without denying that special circumstances might in particular cases justify a choice of the heavier truss, to entitle No. 1. to a preference over No. 1 B.

BRIDGE No II, WITH LOAD ON THE BOTTOM.

	No. 2. Murphy-Whipple Truss.	No. 2 A. Warren Truss.	No. 2 B. Diagonal Truss.
	Units.	Units.	Units.
Theoretical weight, ...	237·8	237·5	228
Weight of transverse stiffening to struts, ...	6·6	16·1	26
Excess of practicable minimum over theoretical minimum, ...	11·98	13·42	32·82
Total weight, exclusive of joints and packings, . .	256·38	267·02	286·82

It thus appeared that No. 2 truss was lighter than either of the others by 4·15 and 11·87 per cent. respectively.

With regard to the peculiarities of detail of the two bridges, it was remarked, that in order that the stress might be uniformly distributed over the surface of any cross section of either "boom," it was necessary that the two halves of the double web of each truss should each support exactly one-half the load upon that truss. This, it was urged, could not be realized by the ordinary modes of fixing the cross girders; but, in the cases under consideration, it was arrived at by supporting the cross girders in the middle of the width of the truss. Thus, in bridge No. I, each cross girder rested upon a light cast iron saddle or bridge, which spanned the width of the top boom, and had its bearing partly upon the top edges of the vertical struts, and partly upon rivets passing through it, the struts, and the vertical side plates of the top boom, in such a way that the line of action of the vertical force transmitted from the cross girder to the truss, coincided exactly with the vertical centre line of its width. In bridge No. II a different arrangement was necessary. In that case each vertical strut consisted of two pairs of angle irons separated in the plane of the truss by a space just wide enough to permit the end of the cross girder to pass in between the pairs. At the same level as the cross girder a plate was riveted to each pair of angle irons; and to the centres of these plates the cross girder was also riveted, so that the weight was equally divided between the four vertical angle irons, and the resulting stress was equally distributed between the two halves of each boom. In both bridges the centre lines of the vertical struts, the diagonal ties, and the top and bottom booms, intersected each other at the centre of gravity of the group of rivets which attached each strut and tie to the boom, and, in order to satisfy the condition of uniform stress, all the centre lines were axes of symmetry. In the top booms of both bridges a section had been adopted which was believed to be new. It was somewhat like an elongated capital letter **H**, or like a common plate

girder placed upon its side; the horizontal web or diaphragm being only sufficiently thick to ensure lateral stiffness. In this section all the centre lines were axes of symmetry, and consequently intersected each other in its centre of gravity; and the horizontal axes were easily made to intersect the centre of gravity of the web-joints. The chief mass of metal was also placed immediately contiguous to the bars of the web, which transferred the stress to the boom, instead of being at some distance from them, as in the trough-shaped and T-shaped form of boom. The material was likewise disposed in the best possible manner for resisting vibration, while this section gave complete facilities for examination and painting. The ends of each truss rested upon hinged bearings by means of cast iron saddles riveted to the junction of the endmost bars of the truss, rollers being provided at one end.

The means adopted in the designs of these girders to obtain the utmost economy of weight consistent with moderate economy of workmanship were: The closest practicable approximation of the average strength to the minimum strength; the observance throughout of the condition of uniform stress, in order that all the compressed members might be trusted with the least possible weight of stiffening; the preference of riveted web-joints to those formed by single pins, and such an arrangement of the riveting that every bar or plate subject to tension should have its whole width, less the diameter of only one rivet hole, available to resist the tensile force applied to it.

Lastly, the author demonstrated the true value of the condition of uniform stress by an exact comparison of the state of a bar of the top boom of the truss of bridge No. II, when under uniform stress, with that condition of unequally distributed stress that would occur if the boom had a suitable trough-shaped section of equal area, breadth, and depth, and therefore of equal nominal value, the elasticity of the material being assumed as perfect. The first case considered was where the stress was uniform in intensity, and the second in which the stress was unequally distributed. The final result was denoted by the equation $p = p_0 \pm \frac{x \, \mathrm{L} \, \mathrm{P}}{\mathrm{I}}$; and applying this formula* to the case of the trough-shaped section of the boom, supposed to be equivalent to the H-shaped section actually used, the following was obtained: The area of section was exactly the same, being 36·17 square inches. The inside depth of the trough, 10 inches, would permit precisely the same disposition of the rivets of the web-joint, so that the centre of pressure was situated at the same perpendicular distance, 5 inches, from the lower

* In this formula, p is the intensity of the stress per unit of area at the distance x from the neutral axis of the stress which intersects the centre of gravity of the section. p_0 is the intensity of the stress considered as uniformly distributed over the surface of section: that is, the total pressure P upon the entire surface of section divided by the area of that surface. L is the perpendicular distance of the centre of pressure from the neutral axis, and I is the moment of inertia of the surface with respect to that axis. x is + or —, according as it is measuree on one side or the other of the neutral axis.—C. R.

edges of the trough, as from the edge of the H-shaped section actually used. The centre of gravity was found to be situated at 8·088 inches perpendicular distance from the lower edge of the trough, and 2·537 inches from the top edge. The magnitude of the total stress upon the section was 125 tons. The uniform intensity of the stress was 3·45 tons per square inch, and the moment of inertia with respect to the axis was 336·892. From these data the greatest stress was found to be 12·717 tons per square inch at the extreme edges or corners of the sides, and the least intensity 0·544 ton per square inch along the extreme bottom of the trough. In this result the effect of flexure was purposely omitted.

In summing up the conclusions sought to be established, it was submitted that—

First, a comparatively small deviation of the centre of the stress, upon the cross section of any bar of any piece of frame-work from the centre of gravity of that section, produced within the limits of elasticity a very great inequality in the distribution of the stress upon that section.

Secondly, if it were conceded that the real strength of every structure was inversely proportional to the greatest strain suffered by its weakest member, then the existence of this unequal distribution of the stress must be detrimental to the strength of any structure in which it existed, and which had been designed upon the supposition that the mean intensity of the stress upon any bar was necessarily a correct measure of its strength.

Thirdly, there was no practical or theoretical difficulty in designing a truss or girder in which the stress upon every cross section, of all the important members at all events, should be absolutely uniform.

Fourthly, the condition of uniform stress was perfectly consistent with the utmost economy of material in the structure to which it was applied.

On a new Method of Working Atmospheric Railways.—By Francis Campin, C.E.

From the London Artizan, Feb., 1865.

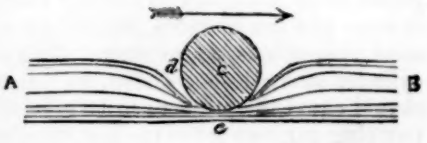
The atmospheric system of railway propulson having been, in several localities, tested as to its practicability and found wanting, appears for some years to have been set aside, no attention being paid to it except by those personally interested in its success; and so the locomotive has had a clear field, having no rival except in one or two instances where the gradients are too heavy for the ordinary mode of working, and stationary power is requisite. Recently, however, the subject of atmospheric propulsion has received attention, as it seems suitable, if its peculiar difficulties can be overcome, for the working of underground railways where the presence of the locomotive is frequently inconvenient. The obvious advantages of a perfect system of atmospheric propulsion are briefly, simplicity of machinery, impossibility

of collision, as two trains cannot meet on one line of rails, nor can one overtake that preceding it; and reducing the weight of the train by displacing the locomotive, and the consequent reduction of wear and tear in the permanent way. The difficulties which have hitherto resisted the practical application of the system are, the mode adopted for connecting the propelling piston to the train of carriages; the continuous valve on the air-tube working very unsatisfactorily; the low pressure at which the propelling power is worked, by the reason that only the atmospheric pressure is available, because if compressed air were admitted within the air-tube, the valve would be blown open and the operation of the machinery stopped; and a valve could scarcely be made to open inwards, as, in that case, it would come in the way of the piston within the tube.

By the method which it is the object of the present paper to describe, any reasonable pressure may be employed, and the difficulty of the valve is obviated by doing away with it entirely. It is the invention of Mr. William Lake, C.E., who has devoted considerable attention to this subject, which is now promising fruitful results to those who shall succeed in practically establishing the utility of the atmospheric railway.

I will now proceed to explain the details of the machinery by means of which it is proposed to conduct the traffic according to Mr. Lake's principle, commencing with the tube and gearing on the carriages.

The air-tube laid between the rails, instead of being rigid, as heretofore, is made of some flexible substance, such as india rubber, upon which runs a roller attached to the bottom of the carriage or carriages to be propelled, the roller also being coated with an elastic substance, and fixed at such a level that it will, by pressing on the tube, collapse and close it at the point of contact. Then, if air be forced into the tube, the roller will be forced along, drawing the train with it, the effect upon the roller being the same as if it were placed upon an inclined plane. The annexed sketch may, perhaps, make the action above described more clear. Let A B represent a portion of the elastic air-tube, compressed so as to be closed by the roller C. If air be forced into the tube at A, then, by reason of the pressure exerted at the point *d*, or rather along the inclined surface *d* of the tube, the roller C is caused to progress along the tube in the direction of the arrow, or from A to B, and *vice versa*. The impelling force will be proportional to the area of the tube A B, and the pressure of the air forced into it, but care must be taken that the diameter of the roller C is properly proportioned to that of the tube A B, or a point may be arrived at where motion will cease, if the roller be continually reduced in size—the larger it is the easier will it work, as the propelling power will have, as it were, a greater amount of leverage; this leverage being proportional to the distance from the centre of force *d*, acting on the roller to the bottom point *e* of the roller.



The first question to be answered as to the practical working of this project on a large scale, is: Will the elastic tubing bear the pressure thrown upon it, and the constant passing of the roller over it? To which it is answered, that not only is it possible to make elastic tubing to fulfil these conditions, but responsible manufacturers are prepared to undertake it, and to guarantee it to a much higher pressure than would ever be required in working, or, in figures, to upwards of 250 lbs. per square inch. Let us now take a case, and determine the size of tube necessary to propel a train at average velocities upon an incline of 1 in 100 rise; the weight of the train will be taken as 50 tons, the speed about 30 miles per hour, and the working effective pressure of the compressed air in the elastic tube 50 lbs. per square inch. In order to be on the safe side, the resistance of the train in rolling friction will be assumed as 20 lbs. per ton.

The resistance from friction will be 50 tons $\times$ 20 lbs. = 1000 lbs.; that due to the incline, 50 tons $\times$ 2240 lbs. $\div$ 100 (ratio of gradient) = 1120 lbs.; total, 1000 lbs. + 1120 lbs. = 2120 lbs. propelling force required; this, divided by the working pressure, gives the area of the working tube. Thus, 2120 lbs. $\div$ 50 lbs. = 42·4 square inches, corresponding to a diameter of 7·375 inches. This size is so moderate that it is evident there is no difficulty about getting the requisite power to propel trains upon any incline—(thus, if the gradient were even 1 in 30, the tube would only need an increase of diameter of from 7·375 inches to 11 inches; and it may here be noted that the roller will be, within certain limits, capable of acting on tubes of varying diameters). Now, let us determine the amount of power requisite to maintain the motion of the train at 30 miles per hour on the gradient of 1 in 100. The propelling force is 2120 lbs., and 30 miles per hour equals 2640 feet per minute, giving for the work per minute 2640 feet $\times$ 2120 lbs. = 5,596,800 foot lbs., requiring for its performance 169·6 horse-power. To run the same train on a level, the work would be 2640 feet $\times$ 1000 lbs. = 2,640,000 foot lbs. corresponding to 80 horse power.

We will now pass on to the means to be adopted for supplying the air at the required pressure to the elastic air-tube. Stationary engines placed at certain points on the line would be employed to force air, not at once into the air-tubes, but into an accumulator, which would at the same time act as a governor. This accumulator would consist of a cylinder with a loaded piston, on which the weight would be such as should equal the pressure to be created in the air-tube; then, if the pumping engine worked too fast, the piston in the accumulator in rising would close the throttle valve, and *vice versa*. In the case of the train leaving one section of tube for another, which would occur at each pumping station, the following course would be adopted to prevent inconvenience arising from the sudden removal of the load from the engine at the previous station:

The train, in passing the end of the section of tube upon which it has been traveling, is caused to act upon a tumbler attached to the permanent way, which tumbler closes the valve admitting air from the accumulator into the elastic air-tube; then the engine pumps air into

the accumulator only, until the plunger therein, by rising, cuts off the steam, and so stops the engine. The same result may be produced in other ways, but the above appears most certain, and, therefore, preferable.

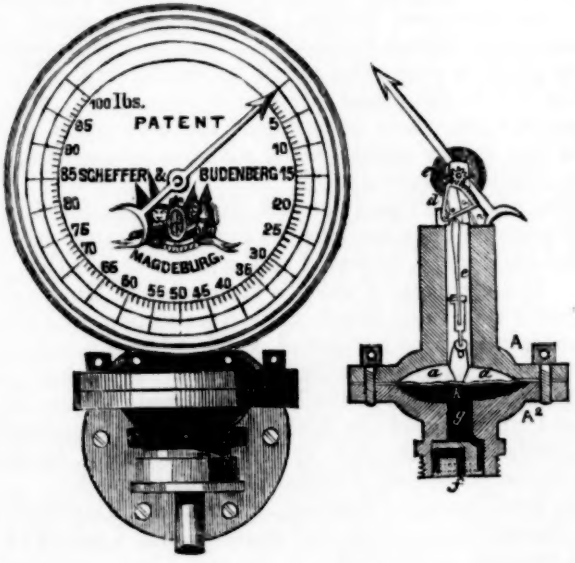
In applying the foregoing method to the propulsion of railway carriages, it is argued that great advantages will be obtained; for the tube is small in size, very durable, and easily replaced; and, further, a uniform speed can be maintained, as the tubes can be increased in size on gradients, the same roller being capable of acting upon tubes of various diameter, as mentioned above, and, by these means, the speed of the train is maintained without raising the pressure in the elastic tube.

Pressure Gauges and other Instruments used in Steam Engineering.

By Mr. A. BUDENBERG.

From the London Artizan, February, 1865.

Letters patent was granted to Mr. Schaeffer early in 1850, by the Prussian government, for the invention of the "Manometer," or Pressure and Vacuum Gauge, which I am about to describe to you, and which has become so great a success, as may be judged by the



fact that, since the 23d of January, 1850, when those letters patent were granted, upwards of 60,000 gauges of that construction have been sold. The well known difficulty to obtain letters patent from the government of Prussia, which is particularly illustrated by the refusal of such for Giffard's Injector, gives some reason to believe

that Schaeffer's invention was entirely new and without precedent, when it is remembered that in Prussia the decisions arrived at in applications for letters patent depend entirely upon this point—whether the presumed invention is entirely new, or whether anything similar to it has been made before.

The following is the description of these gauges, whose construction, however, is so simple, that it explains itself fully by reference to the illustration. Their action is direct. The steam or other fluid which is brought by a tube from the boiler or other vessel, exerts its pressure on a corrugated steel plate, *a a*, which is protected from corrosion by a sheet of pure silver, *k*. The plate is thus deflected upwards, and when the pressure is removed, it returns to its original position. It will thus be perceived that the accuracy of the gauge depends almost entirely upon the perfect elasticity of this steel plate. A small block, provided with a socket-joint, is fixed to the joint, and its motion is transferred to the quadrant, *d*, by means of the connecting pieces, *b* and *c*. This quadrant communicates the motion finally to the index by gearing into a small pinion fixed upon the axle or pivot which carries the index, and the gearing is so proportioned as to multiply that motion sufficiently to render the divisions of the dial clear and legible.

The spiral or hair spring, *e*, regulates the motion of the index, and makes it continuous and steady. The dial shows actual pressures, and is accurately divided to the scale of an open mercurial column, and every gauge is repeatedly tested before delivery. The divisions on the dial are in one pound per square inch, and in atmospheres; sometimes they are made to represent the pressure of a column of water, 34 feet, nearly corresponding with one atmosphere, or fifteen pounds pressure per square inch.

For about two years past our firm have manufactured gauges for hydraulic pressure up to ten tons per square inch, on a principle similar to Bourdon's gauge, improved and modified to suit that particular purpose. These gauges, of which a sample is exhibited, are made of a semicircular steel tube, elliptic in its cross section, into which water (or, in preference, oil) is introduced, which, when it is subject to pressure, tends to straighten or uncoil the tube. A toothed connecting rod is attached to the end of the latter, and made to gear into a small pinion fixed upon the spindle to the index, which registers the pressures as divided upon the dial by actual experiment, as is the case with the steam gauges just described, in tons per inch.

Messrs. Brockhurst and Sullivan, of the firm of Dewrance and Co., formerly Bourdon's agents in this country, took a patent in January last for a pressure gauge similar to the one I have just explained, in so far as regards the semicircular tube. These gentlemen claim that particular construction, and the practice of filling the tube with oil, as some of the principal points of their patent, although our firm had adopted that form of tube a considerable time before them, and have tested in Magdeburg and Manchester the tubes and other springs by the medium of oil, a practice which has been adopted by others as

well as ourselves, long before Messrs. Dewrance and Co. thought it worth their while to take a patent for it.

The only point in Messrs. Dewrance and Co.'s patent, which is as original as it is novel, is the introduction of a valve, whose special function is to close up the aperture which connects the tube with the pressure pipe, and thereby to disconnect the whole mechanism of the gauge from that pipe, the pressure of whose contents it is intended to register. The consequence of this arrangement is, that the gauge will register a certain maximum pressure, but it never indicates any excess of pressure, in case such has been attained; whereas it has been our uniform and careful practice to construct our gauges in such manner that the index shall be thrown out of gear, whenever the maximum pressure which the gauge is intended to register has been exceeded; and I shall leave this meeting to judge of the relative merits of Messrs. Dewrance and Co.'s innovation and of our own practice.

Mr. Birckel said: It was my desire to bring this subject before the Society, because I had noticed that shortly after the lapse of the patent of Bourdon's gauge, which had acquired a certain amount of celebrity, the agents of Bourdon in this country took out a patent for certain alleged improvements in these gauges. I did not then know what these improvements were; but having mentioned the circumstance to Mr. Budenberg, he explained to me their nature, when I found that the only novelty was the valve which is intended to shut off the pressure when it has reached a certain density. I thought that a practice like *that* was so contrary to all we had hitherto done in steam enginering, so contrary to all regulations which had hitherto been issued by the Manchester and other Boiler Associations, the tendencies of which have invariably been to render everything accessible, and to divulge everything that is going on in the boiler, that it ought to receive due publicity. Now, here we have a gauge which, for the sake of its own protection, shuts off the pressure, so as to prevent injury to itself from over pressure, although when that point has been reached any amount of extra pressure might be put on the boiler without any one knowing anything about it. As soon as I saw that, I thought it a subject worth bringing before such a Society as this, in order that its merits or rather its demerits, might be made known to the world. Mr. Budenburg labors under the disadvantage of being a foreigner, and cannot explain himself so clearly as we might wish him to do; but he has endeavored to show you that by them a gauge has been constructed, such that, when the maximum pressure has been reached which the gauge is desired to register, the index shall be thrown out of gear; and when that has taken place, it never again can indicate any pressure whatever, until the maker of the instrument, or any person able to do it, has taken it down and put it into working order again. It registers, therefore, the fact that there has been too great a pressure in the boiler (or other vessel)—it registers that fact, and in so far provides a precautionary measure against accidents from over pressure. The merits of Messrs. Budenberg's gauges may be appreciated

sufficiently by the fact that 60,000 of them have been manufactured and used in the space of fourteen years. It appears, from an inspection of its structure, that the principal element in the gauge is the corrugated steel plate, which really forms the spring, by the deflection of which the amount of pressure is indicated; and I think that the correctness of those indications for any continued length of time entirely depends upon the tempering of that steel plate, and upon the quality of the steel of which it is made. I should think that Mr. Budenberg ought to have a few facts to mention in reference to this, namely, how long any of these plates have been known to work with accuracy, and I shall be very glad to be informed of the length of time their elasticity is likely to remain perfect.

Mr. Budenberg.—I may say that in Manchester and in its neighborhood, where great attention has been paid to the working of steam gauges, ours have given the utmost satisfaction. For instance, the Messrs. Hick, of Bolton, who have been using them ever since we have had them in England, declare that they are the best of all gauges. Last year, at Messrs. Hawthorn's, in Newcastle, Mr. Scott, the engineer, told me they had one of our gauges on one of their boilers for eleven years, which had continued true during the whole of that time, while gauges of other makers had become quite incorrect after a space of two years.

Mr. Dawson.—The Secretary's inquiry was as to the quality of the steel.

Mr. Budenberg.—That is decidedly the most important part of our gauges, namely, the quality and the tempering of the steel; and the secret of our success lies in the fact that we have had all the springs tempered by one man. Mr. Shobelt, who is present, is one of our oldest hands, and he can tell you that the making and the tempering of the plates, and the making of the socket-joints, are the most difficult and, at the same time, most important points in our gauges. We have only employed one hand for each of these parts, and have never deviated from this rule. By practising things in this way, we have been able to produce a good article; but had we employed a new man every fortnight or so, we would never have made a good gauge. The corrugated steel plates are tempered in oil; and this is a nice operation; for they must not be too hard, and yet they must be hard enough. The other parts, however, must also be well made; for although the steel plate were perfect, if the other parts were not made carefully, the gauge would not move freely, and therefore not indicate correctly. According to our experience, no metal will do for the spring except steel, and we invariably use cold drawn Sheffield steel.

Mr. Maxwell Scott.—I consider it a very satisfactory point that these gauges will throw themselves out of gear in case a pressure has been attained beyond that which they are made to indicate. This feature, I think, is not generally known; for although Mr. Budenberg has several times called on me with these gauges, he never mentioned that circumstance to me before. I should like to ask the method of

forming the corrugations in the steel plate, whether they are stamped as candlesticks and such things are done, or otherwise? I should like to know also the thickness of the steel-plates, and how the difference in the thickness of different plates is compensated for in the graduation of the dial, whether by the tempering, or by the hair spring in connexion with the index?

Mr. Budenberg.—The fact is, we require different thicknesses of steel for gauges of different range of pressure, and we have a great deal of trouble at times to get steel of the thickness we want it. I think it is No. 36 (wire gauge) we generally use; that is the finest steel we use, and we have had a great deal of trouble to get it so fine. We had at one time an order from Mr. Collett, of the St. Katharine Dock Company, to make a gauge to indicate the pressures of a column of water ranging up to four feet. The lowest point of the reservoir was at an elevation of eleven feet, and he had an idea that the index-hand should go thrice around the dial for these eleven feet; and that for the four feet, of which he desired to register the varying heights, it should make a complete revolution, and indicate every fourth of an inch of height of water. We tried to make the gauge as proposed to us, but could not succeed; and Mr. Schaeffer at last accomplished it in a different way. Some of the teeth of the quadrant were cut away, so that it should not begin to indicate until the eleven feet of water were on; and in this manner it has been working satisfactorily for four years. As for the plates, they are stamped.

Mr. M. Scott.—Would not a column of mercury be better for such a purpose?

Mr. Budenberg.—I thought so too at the time, but it is now made and working well at this time, as I may refer you to Mr. Collett, of the St. Katharine Docks. Through his recommendation, based on the working of this gauge, we have our gauges in use everywhere in these docks. Mr. Anderson, of Woolwich Arsenal, is also very favorable to them, and he has them in use extensively throughout the gun factory.

Mr. Scott.—How do you compensate for different degrees of deflection of different thicknesses of plates in the gauges?

Mr. Budenberg.—We have to mark the divisions of the dial for every single pound of the range, by testing with a mercury column; we try them very often over, and we mark off every single pound. Every gauge is marked off in this way; we could not make two gauges to one pattern. There are no two dials exactly alike; it is with them just as with human faces, they look sometimes very like one another, but there is a difference when you examine them.

Mr. Clay.—It would be very difficult to manufacture the plates of the same thickness.

Mr. Budenberg.—This spring has no compensating effect; every plate is tried separately. It is often necessary to put the markings out again; we have to go over this operation several times before we can put the pressures on the dial finally.

Mr. Smith.—I should rather have had a description of different kinds

of gauges than a description of Mr. Schaeffer's gauge. Mr. Schaeffer's gauges, like others, are difficult to repair; and I think it would be a good thing to use a relief-valve like that proposed by Mr. Dewrance, if it was possible to make the valve so as to blow a whistle when it was open, and thus indicate that the limit of safe pressure had been exceeded. There is such a variety of gauges in use, that I do not know the difference between them. I should have liked to have heard from our Secretary, who is so well versed in all these matters, the history of pressure gauges, and their peculiarities. Its cheapness is no doubt a recommendation to Mr. Schaeffer's gauge. This may be accounted for by its coming from Germany, where labor is cheaper than with us, but I know that the gauge is really an excellent one. The mercury column is as good a gauge as can be constructed, and I have been told that an improved mercurial gauge has been introduced. I should have liked to have heard a description of it.

Mr. Birckel.—I think it is too much of Mr. Smith to expect that Mr. Budenberg will come here to blow anybody else's whistle but his own. There are so many different gauges, both in use and out of use, that it would be very difficult for me to go into the history of steam gauge construction. I believe that the two principal gauges known are Schaeffer's and Bourdon's. There is Smith's, and various others, but I do not know the peculiarities of their construction. The principle of construction of Bourdon's gauge has been illustrated to the meeting to-night, as one of these gauges has been passed round the room. The mode of action of Bourdon's tube is to partly uncoil itself under an internal pressure, and the extent to which it is straightened is registered in much the same way as in Schaeffer's gauge.

Mr. Budenberg.—The principle of Bourdon's is so far different from ours, that in the latter the elastic medium is a plate, and in the other it is a tube, and the expansion or uncoiling of the tube turns the index.

Mr. Birckel.—Mr. Smith was saying that the mercurial gauge was as good as any other gauge; but I think it right to state that the mercury gauge is the standard of this, and should be the standard of any other gauge, so that when you measure pressures by means of this gauge, you only read the indications transferred from the open mercurial gauge to this one.

Mr. Clay.—There was a gauge invented by Mr. Alexander Allan; probably Mr. Grey can enlighten us about it.

Mr. Budenberg.—It is not much in use, except only on the locomotives of the line with which he is connected. It is filled with water, I believe, and is something like a closed mercurial gauge, or compressed air gauge, only the medium here is filled with water. There is always a deal of mischief in air gauges, and on the Continent they are entirely condemned. In Prussia you would not be allowed to put one of them on a boiler. The present law in Prussia, which I believe to be quite good, is, that you must have a mercury column in every boiler house. You may have a gauge such as ours on every boiler, but you must have also a mercury gauge connected with the others, and so

arranged that they each and all may be shut off and tested severally, in order to ascertain whether they are working alike, and in harmony with the mercurial gauge. I have a copy of the law with me, and I think no objection to it can be seriously made. It says; "The law that each boiler must have a separate gauge remains in force, but the choice of construction is free, and we recommend, on account of their practicability, and because they can easily be read off, the use of spring gauges, but we require them to be often compared with the controlling gauge." That is to say, suppose you have twelve boilers, every boiler would have one gauge; and in a corner of the house an open mercurial column is placed, and is connected with all these gauges. You have a tap to shut off each of them, but from time to time you have to test them, or perhaps the inspector comes round and sees whether they are all working alike. That is the present Prussian law.

On the Wear and Tear of Steam Boilers. By FREDERICK ARTHUR PAGET, Esq., C.E.

(Continued from page 20.)

From the Journal of the Society of Arts, No. 649.

2.—*The Mechanical Effects of the Heat.*

While a maximum of stiffness to the mechanical action of the pressure is required in a steam boiler, a maximum of flexibility to the irresistible mechanical force of heat is of no less importance. For instance, a great advantage of some of the forms of strengthening rings for internal flues is that they allow the use of thinner plates; together forming a structure of great flexibility to complicated thermal influences. The longitudinal expansion of inside flues like this is taken up by a slight spring or swagging at each joint, and the end plates of the shell are not unduly strained by the combined efforts of the internal pressure and the expansion due to heat. This is one way in which defective circulation, or a sudden current of cold air or of water, can act on the structure, by unequally straining the plates; and, although it seems probable that the effects said to have been thus produced, are, to some extent, due to other causes, they point to the importance of keeping the temperature of the plates as low as possible. One protection against effects of this kind is the gradual diffusion of heat, produced by its conduction to and from the different plates. It is a general belief with engineers that a pressure of steam strains a boiler more than cold hydraulic pressure; but it is unsettled as to what amount and in what exact way. The basis of an examination of the kind would have to be sought in an exact determination of the temperature of a plate which is transmitting the heat to the water, and this has not yet been determined with any accuracy. The fact is, as is remarked by M. Péclet, who has given great attention to these questions, the different phenomena involved are extremely complicated. It is clear that the plates must always be at a higher temperature

than the water, as it is by the difference of temperature of the two surfaces of the plate that it is traversed by the heat. He supposes that, though the plate is inversely as its thickness (while it is directly as the surface and as the difference of temperature between the outside and inside faces), yet the flow of heat would be the same through a thicker plate, from the greater difference of temperature between the two surfaces.* He does not seem, however, to be aware of the important law demonstrated by Mr. J. D. Forbes, that the conducting power of, for instance, wrought iron, rapidly diminishes at the higher temperatures. At 200° C. it has little more than one-half the conducting power it has at 0°.† At yet higher temperatures it might probably be proved, if an applicable instrument for registering higher temperatures were in existence, that the powers of conduction are still less. Some of Mr. Péclet's experiments also seem to be vitiated by his disregard of Dr. Joule's discovery that water is heated by being mechanically stirred up. It is, however, certain that water can only moisten a metallic plate when at a lower temperature than 171° C. As soon as the water gets thus repelled, the heat radiated by the metal is reflected back from the surface of the liquid; the metal gets hotter and hotter, with a corresponding diminution of its conducting powers; its outside, exposed to the fire, would more or less oxidize, and with a similar result; and a like effect is produced on the inside—on the roughened surface of which incrustation would rapidly adhere, forming a calcareous coating, conducting with about sixteen times less power than iron.‡ All these tendencies are of a progressive character, leading to very high temperatures in the plate, even to a red-heat. This tends to explain how rivet-heads close to the fire are soon burnt away by the friction of the current of heated gases on the red-hot metal; how thick fire boxes are sooner burnt out than lighter ones, the process being often arrested at a certain thickness; how internal flues of thick plates so often give trouble; how externally fired boilers are most deteriorated at the corners from the junction of the three plates; and similar results well known to practical men. Another proof that thin plates conduct more heat than thick plates is afforded by some experiments lately made in Prussia, with two egg-end boilers, exactly similar in every respect, except that one was constructed of steel plate ¼-inch thick, while the other was of wrought iron about ½-inch thick. The steam generating power of the steel boiler was to that of iron as 127·49 to 100§—a result which can only be accounted for by the thickness of the plates. Thick plates are also more liable to blisters, one of which would considerably diminish the conduction power of the spot where it happened to form.

* Traité de la Chaleur. Vol. II, page 393.

† Royal Society of Edinburgh, 28th April, 1862. "Experimental Inquiry into the Laws of the Conduction of Heat in Bars, and into the conducting power of Wrought Iron."

‡ Traité de la Chaleur. Vol. I, page 391.

§ Verhandlungen des Vereins zur Beförderung des Gewerbfleisses in Preussen, 1862, p. 140.

While it is certain that boiler plates can assume very high temperatures, even up to red-heat, authorities differ as to the diminution of ultimate strength which is caused by heat, while its effect on the elasticity of the plate has been scarcely attended to. The experiments on the ultimate tenacity of iron at high temperatures, conducted by Baudrimont,* Seguin, and the Franklin Institute, can scarcely be looked upon as of much value, for they were made on a very small scale, and with no regard to the temporary and permament elongations—or to the effect of heat on the elasticity and ductility.

Mr. Fairbairn† observed no effect on the strength of plate iron up to almost 400° F. At a "scarcely red" heat the breaking weight of plates was reduced to 16·978 tons from 21 tons at 60° F.; while at a "dull red" it was only 13·621 tons. MM. Tréméry and P. Saint Brice,‡ aided by the celebrated Cagniard Latour, found that at nominally the same temperature (*rouge sombre*), a bar of iron was reduced in strength to one-sixth of its strength when cold. This is much greater diminution of strength than that found by Mr. Fairbairn. Apart from other causes this might easily be due to the fact that incandescent iron affords a different tinge during a dull day to what it does in a clear light. In fact, the great impediment to all these investigations is the want of a thermometer for high temperatures; but M. Tréméry's result is perhaps more conformable with daily experience. Mr. Fairbairn's data would show that the ultimate strength of wrought iron is reduced to about one-half; but M. Tréméry's result explains the generally instantaneous collapse of flues when red-hot, and which have been, of course, originally calculated to a factor of safety of *six*.

A most important question is the effect of temperatures, whether high or low, on the elasticity of the material—whether iron will take a permanent set with greater facility at a high temperature? These data are really more important than those on the ultimate strength, as they would show the influence of temperature on the elastic limit. Here again is a vacancy in existing knowledge, which can scarcely be said to be filled up by the few experiments of the late M. Wertheim on very small wires.§ He found, however, that the elasticity of small steel and iron wire "increases from 15° C. to 100°, but at 200° it is not merely less than at 100°, but sometimes even less than at the ordinary temperature."

There is, however, another important point with respect to wrought iron, which has scarcely received the attention it deserves. As would appear from a number of phenomena, there seems to be a sort of thermal elastic limit with iron. When heated, and when its consequent dilatation of volume does not exceed that which corresponds to (perhaps) boiling point, it returns to its original dimensions. Beyond a certain

* "Annales de Chimie et de Physique," 3, s. 30, page 304, 1850.

† On the Tensile Strength of Wrought Iron at Various Temperatures. Reports British Association, 1856, page 405.

‡ Annales des Mines. 2 serie. Vol. III, page 513.

§ Comptes Rendus, xix, 231.

temperature it does not contract again to its pristine volume, but takes a permanent dilatation in consequence, apparently, of its elastic limits having been exceeded. A number of observers* have determined the fact with cast iron, and though wrought iron has not been expressly investigated in this direction, there is no doubt that it exhibits a similar behaviour. Thus, a number of years ago,† an Austrian engineer named C. Kohn, remarked that a boiler about 12 metres long and 1·57 in diameter, with a thickness of plate of 0·011, permanently expanded, at a temperature corresponding to a steam pressure, of 5 atmospheres, (153° C.) by 0·07193, and did not, when cold, return to its original dimensions. The same thing has been noticed, by means of very accurate measurements, with other boilers. A number of experiments by Lt. Col. H. Clerk, of Woolwich, on wrought iron cylinders and plates,‡ bear distinct evidence to a dilatation of volume in wrought iron, when repeatedly heated and suddenly cooled. In experiment 7, for instance, "two flat pieces of wrought iron, each 12 inches long, 6 inches deep, and ½-inch thick, were heated and cooled 20 times, one being immersed to half, and the other to two-thirds, its depth in water. That immersed one-half contracted or became indented on the ends fully ·3 inch; the other had similar indentations, but only to one-half the amount. They both turned up into the form of an arc," the *convex* side of which appeared in the portion heated and cooled. Unfortunately, the specific gravities of the different portions were not tried by Colonel Clerk. A succession of trials of the kind produced cracks in the metal, thus explaining how boiler plates are cracked by imperfect circulation and by cold feed-water let in near the fire; and, the thicker the plate, the more permanent dilatation of volume and consequent danger. Mr. Kirkaldy found that "iron highly heated and suddenly cooled in water, is hardened," being injured, in fact, if not afterwards hammered or rolled. This permanent dilatation of volume must be necessarily accompanied with a diminution of specific gravity, thus affording another close analogy, betweeen straining iron by loads in excess of the mechanical elastic limits, and straining by heat. Lajerhelm§ found, long ago, that the specific gravity of iron is diminished by strains in excess of the limit of elasticity, and this result has been completely confirmed by Mr. Kirkaldy's numerous experiments. The smith calls iron "burnt" which has been rendered brittle in working through the often repeated applications of heat, or through too high a temperature. Iron rendered brittle by strains in excess of the limit of elasticity has been long popularly termed "crystallized." Both these states are accompanied with a dilatation of volume and attendant hardness and brittleness, and both seem to be referable to very similar causes. In fact, a very general belief exists that very ductile good iron, used in the form of a steam boiler, soon gets brittle. There are some applications of metal to a steam boiler peculiarly liable to

* Percy's Metallurgy, vol. ii, page 872.

† Technologiste. 1850-51, page 102.

‡ Proceedings of the Royal Society, March 5, 1863.

§ Poggendorf's Annalen, 2, s., vol. ii., page 488.

be strained beyond the limits of elasticity; by mechanical force, by the mechanical force of expansion and contraction, and by dilatation of volume through heat—all three acting simultaneously. Such is the case with fire-box stay-bolts. Accordingly, they are found to get very brittle when of wrought iron—which is a much less ductile metal than copper. Mr. Z. Colburn states that he has "frequently found these stays (where made of wrought iron) to be as brittle, after a few years use, as coarse cast iron." He has "broken them off from the sides of old fire-boxes, sometimes with a blow no harder than would be required to break a peach-stone."*

The Chemical Effects of the Incandescent Fuel.

Whatever physical changes may be induced in iron by the long continuance of a high temperature which is not succeeded by the application of the impact of the hammer or the pressure of the rolls, it is certain that long-continued red-heat leads to the loss of its metallic consistency. Its surface gets converted to a greater or less depth into forge scales, which, according to Berthier, consist of a crystallized compound of peroxide and protoxide of iron. The mechanical action of the gases—and especially of the free oxygen contained in every flame—forced at a high velocity by the draft past the more or less heated plates, would also aid these chemical combinations—upon the same principle as iron filings, thrown through a gas flame, burn in the air; and upon the same mechanical principle as the incandescent lime is worn away by the flame of the oxyhydrogen blow-pipe. These actions would take place with any fuel, even with pure charcoal. But when mineral fuel, which mostly contains more or less iron pyrites, is used, there is much more danger to the plates, especially over the fire, in getting red-hot, as the flames would then hold sulphurous acid, and often volatilised sulphur. A familiar illustration of an action of this kind is afforded by the fact that a piece of red-hot iron plate can be easily bored through by means of a stick of sulphur the combination forming sulphide of iron. Dr. Schafhaeutl, of Munich, has given great attention to the changes in plates subjected to the action of fire; twenty-five years ago he read a paper before the Institution of Civil Engineers,† and more recently he has published an essay, both on this subject, in a Munich periodical.‡ He has brought forward a number of facts, founded on chemical analyses of plates of exploded boilers, showing the danger, due to chemical action alone, when the plates of a boiler become red-hot. He notices that the iron of the inside of the plates, in getting red-hot decomposes the water, and combines with the oxygen thus freed. It also loses some of its carbon. The outside combines with the free oxygen and with any sulphurous acid in the flame. He states that iron made with pit coal is much more affected than charcoal made iron; becoming laminated at the original joints in the pile out of which the plate has been rolled. It is possible that

* Steam Boiler Explosions, 1860, p. 32.

† Transactions of the Institution of Civil Engineers. Vol. III, 1840, p. 435.

‡ Bairisches Kunst und Gewerbeblatt. June, 1863.

portions of oxide are carried into these joints, and it is at any rate certain that iron gives way easiest at these places. This points to the great value of really homogeneous plates, such as those of cast steel, in which homogeneity has been obtained by the only known means of fusion. The remarkable diminution of elasticity and of tenacity caused by the combination of the red-hot iron with sulphur; the absence of all elasticity and tenacity in the oxides of iron, show that, even if a flue do not at once collapse, or a shell explode, through getting red-hot, the boiler is more or less injured every time it gets overheated. A defective circulation, by permitting such a temperature as to drive the water off the plate, would soon lead to local injury. Particular spots in externally fired cylindrical boilers are sometimes, as is stated by Mr. L. Fletcher, of Manchester, thus affected, and in an apparently mysterious way. A new boiler in which a heap of rags were accidently forgotten, had the spot burnt out in a few days,* doubtless through the resulting defective circulation and its consequences. The plates just above the fire of internal flues also suffer in this manner. It is perhaps possible that turned joints, secured by bolts, and allowing an occasional reversing, or rather rotating, of the ring, might, in some cases, be here of service. At any rate, universal experience proves that the thicker the plate the easier does it get red-hot; and these chemical facts also point to the desirability of a minimum of thickness. In fact, the wearing away of the plates through these causes, if mechanically strong against pressure, often gets arrested at a certain thickness. In Germany and France, some of the best manufacturers still make the plate over the fire of, for instance, inside flues, slightly thicker than anywhere else; but the combined chemical and mechanical actions of the heated fuel cause most wear and tear in a thick plate, and thus justify American practice in this respect. In that country, fire-box plates of good charcoal iron are made only $\frac{5}{16}$ or $\frac{1}{4}$ of an inch thick, and with stays four inches apart, give good results under nearly 150 lbs. steam pressure.

(To be continued.)

MECHANICS, PHYSICS, AND CHEMISTRY.

On Chemistry Applied to the Arts. By Dr. F. Crace Calvert, F.R.S., F.C.S.

From the London Chemical News, No. 242.

Continued from vol. xlix, page 329.

Leather.—The art of the currier. Morocco, Russia, and patent leathers. The art of tawing skins. Chamois and glove skins. Parchment. *Hair*, its composition and dyeing. *Wool*, its washing, scouring, bleaching, and dyeing. *Silk*, its adulterations and conditioning.

Lecture III.

Delivered on Thursday evening, April 14, 1864.

I shall have to crave the indulgence and patience of my audience during this lecture, as it will chiefly consist of descriptions of processes

* Péclet, Traité de la Chaleur. Vol. II, page 73.

for the most part well known to manufacturers and others engaged in the leather trade. Thus the art of currying, which is applied principally to such leathers as are intended for the upper parts of shoes, for harness, &c., is carried on at the present day nearly as it was fifty years ago, and still is but little known to the public.

Currying.—The objects in view in currying leather are several: to give it elasticity—to render it nearly impermeable—to impart to it a black or other color, and, lastly, to reduce it to uniform thickness. These colors are imparted by the following processes:—After the leather obtained from hides, or the thicker qualities of skins, has been damped, it is placed on a stone surface and energetically rubbed—first with a stone, then with a special kind of knife called a slicker, and lastly with a hard brush. The leather is then ready to be stuffed or dubbed, which consists in covering it on the fleshy side with tallow, and hanging it in a moderately warm room; and as the water contained in the leather evaporates, the fatty matter penetrates into the substance of the leather and replaces it. The dubbing process is then repeated on the other side of the leather, which is now ready to be softened and rendered flexible, which is effected by rubbing it with a tool called a pummel. The leather then undergoes the last mechanical operation, which reduces it to uniformity of thickness by shaving off the inequalities of its surface by means of a peculiarly shaped knife called a slicker. The greatest part of the curried leather is blackened on the grain side by rubbing it with grease and lamp-black, and lastly brushing it over with a mixture of grease and glue. I believe that some kinds of curried leather are dyed by a purely chemical process, in rubbing the tanned skin, first with iron liquor, and then with a solution of gall-nuts or other tanning substance. The most tedious of the foregoing processes is that of dubbing, which has been greatly improved of late years by the Americans. The scoured skins are placed in a large revolving drum, of ten or twelve feet diameter, and lined inside with wooden pegs. A certain quantity of tallow is then introduced and the whole set in motion, and whilst the hides are thus tossed about, a current of warm air is passed through the drums, which carries off the moisture and allows the grease to penetrate the hide. By this means thick hide leather can be stuffed in four or five days.

Split Leather.—A large branch of trade has sprung up within a few years owing to the invention of machinery for splitting hides, skins, and kips, by which, although the quantity of leather has been considerably increased, I am afraid it is at the expense of its quality.

Fancy Leathers.—Allow me now to give you a slight insight into the methods of preparing various fancy leathers, such as Morocco, Russia enamelled, tawed, or kid leather, used for soldiers' belts, gloves, &c., and, lastly, oiled leathers used for wash-leather, gloves, &c. Until the middle of the eighteenth century, Morocco leather was wholly imported from that country, for it was in 1735 that the first Morocco works were established in Paris, and similar manufactories were soon set up in various parts of the Continent and in this country. The process by which Morocco leather is prepared is as follows: The

goat and sheep skins, which are especially used for this branch of manufacture, are softened, fleshed unhaired, and raised or swelled by methods similar to those already described, but one essential element of success in this kind of leather, lies in the perfect removal of all lime from the skins, which is effected by plunging the well-washed skins in a bath of bran or rye flour, which has been allowed to enter into a state of fermentation. The result is, that the lactic and acetic acids generated by fermentation of the amylaceous substances combine with the lime and remove it from the skins. The other essential point is the mode of tanning the skins. Each skin is sewn so as to form a bag, and filled, through a small opening, with a strong decoction of sumac, and after the aperture has been closed, the skins are thrown into a large vat containing also a decoction of the same material, After several hours they are taken out, emptied, and the operation is repeated. To render these skins ready for commerce it is necessary to wash, clean, and dye them. The latter operation was formerly tedious, and required great skill, but since the introduction of tar colors, the affinity of which for animal matters is so great, it has become comparatively easy. The skins, after they are dyed, are oiled, slightly curried, and the peculiar grain, characteristic of Morocco leather, is imparted to it by means of grooved balls or rollers. There are two inferior kinds of Morocco leather manufactured, viz: those called *roan*, prepared in a similar way to Morocco, but not grained, and *skivers*, also prepared in the same manner, but from split sheep skins. I owe to the kindness of Mr. Warren De la Rue, the beautiful specimens of leather before me, which will enable you to appreciate the various qualities of these interesting productions.

Russia Leather.—The great esteem in which this leather is held is owing to its extreme softness and strength, its impermeability, and resistance to mildew, which latter property is imparted to it by the use of a peculiar oil in its currying, that is birch-tree oil, the odor of which is well-known as a distinguishing feature of Russia leather. As to its preparation I will merely state that it is very similar to that of Morocco, with these differences, that hot solutions of willow bark are used instead of sumac; that it is generally dyed with sandal wood and a decoction of alum; and, lastly, as already stated, the birch-tree oil is used in currying it.

Enamel Leather.—This class of leather is usually prepared with calf and sheep skins tanned in the ordinary manner. They are dyed black by rubbing them over with a decoction of logwood, and then iron liquor or acetate of iron. The leather is softened with a little oil, and is ready to receive a varnish, which is applied by means of a brush, and composed of bitumen of Judea, copal varnish, oil varnish, turpentine, and boiled oil.

Tawed or Kid Leathers.—The manufacture of this class of leathers differs entirely from those already described, as their preservative qualities are imparted by quite different substances from those used with other leathers, the preservative action of the tannin being substituted by that of a mixture of alum and common salt. Let us examine

together a few points connected with the production of this class of leather. One of the most interesting characteristics is the method of unhairing sheep, lamb, and kid skins, after they have been well washed and fleshed on the beam. The old process of unhairing by smearing on the fleshy side with a milk of lime, was improved by mixing with the lime a certain amount of orpiment, or sulphuret of arsenic, but Mr. Robert Warrington having ascertained that the rapid removal of hair in this case was not due to the arsenic, but to the formation of sulphuret of calcium, proposed, with great foresight, the following mixture as a substitute for the dangerous and poisonous substance called orpiment—viz: three parts of poly-sulphuret of sodium, ten parts of slacked lime, and ten parts of starch. The poly-sulphuret of sodium may be advantageously replaced by the poly-sulphyret of calcium. The skins, unhaired by any of these processes, are now ready to be placed in a bran or rye bath, as with Morocco leather, or in a weak solution of vitriol, to remove, as already stated, the lime. After the lime has been thoroughly removed from the skins, they are dipped in what is called the white bath, which is composed, for 100 skins, of 13 to 20 lbs. of alum, and 4 to 5 lbs. of chloride of sodium or common salt, and the skins are either worked slowly in this bath or introduced into a revolving cylinder to facilitate the penetration of the preservative agent, which, according to Berzelius, is chloride of aluminium resulting from the action of the chloride of sodium on the alum. When the manufacturer judges that the skins have been sufficiently impregnated with the above mixture, he introduces them into a bath composed of alum and salt in the same proportions, but to which is added 20 lbs. of rye flour and 50 eggs for 100 skins. After remaining a few hours they are removed, and allowed to dry for about fifteen days, and are then softened by working them with a peculiar iron tool, and the white surface which characterizes that class of leather is communicated to them by stretching them on a frame and rubbing them with a pumice-stone. A large quantity of tawed leathers are also preserved retaining their hair, which is done by simply suppressing the unhairing and rubbing processes.

Chamois, Wash, or Oiled Leather.—This class of leathers are named from the fact that formerly they were exclusively produced from the skin of the chamois, but at the present day sheep, calf, and deer skins, and even split thin hides, are manufactured into this kind of leather. I should also state that the employment of this kind of leather has greatly decreased of late years, owing to the general substitution of woolen fabrics in articles of clothing. You will see by the following description that the preparation of this class of leather differs entirely from those previously detailed; the conversion of skins into leather, or from a substance subject to putrefaction to one free from that liability, being no longer affected by tannin, as in the case of hides, and Morocco and Russia leathers, or by the use of mineral salts, as in the case of tawed leathers, but by that of fatty matters, especially animal oils, such as sperm. The skins are prepared in the same manner as for tawed leathers, and then submitted to what is called the

prizing operation, which consists in rubbing the hair side of the skin with pumice-stone and a blunt tool or knife, until the whole of the rough appearance is removed, and the skin has acquired a uniform thickness. They are then worked on the peg until the great excess of moisture has been wrung out, and plunged into the trough of a fulling mill, to the action of the wooden hammers of which they are subjected until nearly dry. They are then placed on a table and oiled, and several of them, after being rolled together, are replaced in the trough of the fulling mill. When the oil has been thus worked into the substance of the skins, they are removed, exposed to the atmosphere, again oiled and, once more subjected to the fulling mill; after which they are placed in a moderately heated room for a day or two, the object of which is two-fold, viz: to facilitate the evaporation of water and the penetration of the oil, and to create a slight fermentation, by which the composition of certain of the organic substances have undergone such modification as to enable them to combine in a permanent manner with the fatty matters. These processes are repeated until the manufacturer deems the leather sufficiently prepared to be fit to undergo the following operations, viz: to be immersed for several hours in a caustic lye bath, to remove the excess of oily matter, washed, and pegged. It is only necessary to stretch the leather on a table, then on a horse, and lastly between rollers, after which it is ready for the market. The ordinary buff color of these leathers is communicated by dipping them, previously to the finishing processes, into a weak solution of sumac. Before speaking of the further processes necessary to fit these leathers for the glove manufacturer, allow me to have the pleasure of describing that of Mr. C. A. Preller, whose mode of preparing leather is very interesting, owing to the rapidity with which he converts hides into leather, and also to the remarkable toughness which his leather possesses. To attain these desirable ends Mr. Preller proceeds as follows: The hides are washed, slightly limed, unhaired, fleshed, and partially dried; they are then smeared with a mixture, made of fatty matters and rye flour, which having been prepared a few days previously has entered into fermentation, and which has so modified the fatty matters as to render them more susceptible of immediate absorption by the hide. I think that this feature of Mr. Preller's plan deserves the serious notice of all engaged in the manufacture of oiled leathers, as it appears to prove that fatty acids (or modified fatty matters) are better suited for combination with skins than neutral fats. The hides, with additional fatty matters, are then introduced into the large American drums, previously noticed in speaking of currying, and after four days they are removed, washed in an alkaline fluid, worked with a pummel and slicker, and after being dried they are ready for market.

Gloves.—The manufacture of this article is now a most important branch of trade, and is the means of giving employment to large numbers of people in several towns in this country as well as on the Continent. To render the above-mentioned oiled leather sufficiently soft and pliable for gloves it is necessary to submit it to the following fur-

ther operations: The chamois, kid, or other skins are rubbed over with a solution composed of one pound of soap, dissolved in half a gallon of water, to which is added 1½ lbs. of rapeseed oil and twenty yolks of eggs, or, what has been recently found to answer better than eggs, a quantity of the brains of animals reduced to pulp. The use of the two latter substances is extremely interesting in a scientific point of view, for they both contain a peculiar nitrogenated matter called vitalline, and special fatty matters called oleophosphoric and phosphoglyceric acids, which doubtless, by their peculiar composition, communicate to the skins those properties which characterize this class of leather. The skins are then washed and dyed in various colors, after which they are softened and rubbed with an instrument adapted to slightly raise the surface, and give it that well-known velvetty appearance belonging to glove skins. I shall not take up your time by entering into the details of dyeing these leathers, but describe the following process for bleaching them:

Bleaching of Skins.—The only process known until recently for imperfectly bleaching chamois and glove skins was that of submitting them to the influence of the fumes of sulphur in combustion or sulphurous acid, but latterly two modes of attaining that object have been proposed. The first consists in dipping skins for two days, in a weak solution of neutral hypochlorite of soda, washing, drying, and rubbing them with soap and oil. The second mode is to dip glove skins into a solution of permanganate of potash, when they soon assume a brownish color, due to the liberation of the oxygen of the permanganate of potash, and the fixation of the hydrate of sesquioxide of manganese by the skin. The skins so acted on are washed and then dipped in a solution of sulphurous acid, which becomes converted into sulphuric acid by the action of the oxygen of the sesquioxide of manganese, and the protoxide thus produced unites with the sulphuric acid, which is soluble in water. The skins thus bleached when dressed are ready for market.

Gilding of Leather.—The usual mode of ornamenting leather with gold is to apply, in such parts as are desired, a thick solution of albumen, covering those parts with gold leaf, and applying a hot iron, when the albumen is coagulated and fixes the gold. This plan is objectionable when the goods are intended for shipment, and the following method, lately proposed, is far preferable: On the parts required to be gilt, a mixture, composed of five parts of copal and one of mastic, are spread; a gentle heat is applied, and when the resins are melted the gold leaf is spread upon them.

Parchment.—There are two distinct qualities of this valuable material, which has been used from time immemorial as a means of preserving records. The best quality is prepared from young lamb, kid, and goat skins, and the second quality from calf, wolf, ass, and sheep skins. To make parchment, the following is the process: The skins are stretched on strong rectangular frames, limed, unhaired, fleshed very carefully, and rubbed with pumice-stone until the skins have acquired the proper thickness. They are then dried very carefully in the shade.

Dialysis.—Thomas Graham, Esq., Master of the Mint, has lately drawn the attention of the scientific world to a most remarkable property possessed by organic membranes of separating, when in solution, crystallizable bodies from those which are not so. The former he names crystalloids, and the latter colloids. For instance, if a solution of sugar (crystalloid) is mixed with one of gum (colloid) and placed in the vessel, the bottom of which consists of a septum of animal or vegetable parchment, the crystalloid sugar will pass through the membrane into the surrounding water, whilst the colloid gum will remain in the vessel. Again, if solutions of iodide of potassium and albumen be mixed together, the iodide of potassium will diffuse itself through the membrane, which the albumen will not do. Also, if to an alkaline solution of silicate of soda, weak hydrochloric acid be cautiously added, chloride of sodium will be produced, and the silica will remain in solution; and if such a solution be placed in the dialyser, the chloride of sodium (the crystalloid) will diffuse itself through the membrane, while the silica (the colloid) will remain behind. It is impossible to calculate the immense service which the discovery of these facts by Mr. Graham will render to physiology, toxicology, or to manufactures, as, in fact, every day new applications of it are being made in these various departments of human research. Thus, to give an example which has special reference to these lectures, I have lately seen it proposed by Mr. A. Whitlaw to place salted meat in large dialysers, when it is stated that the salt only will be removed, leaving all the nutritive properties of the meat undiminished. Mr. Whitlaw also proposes to dialyse the brine in which meat has been salted, and thus to remove the salt, leaving the juice of the meat available for use, while the salt is again in condition to be employed as before.

It will now be my agreeable duty to examine with you a few facts relating to hair and wool. It is interesting to observe that hair, wool, feathers, nails, and claws may be all considered as prolongations of the epidermis, and present nearly the same chemical composition, as will be seen by the following table:

	Epidermis of man.	Hide.	Man's nails.	Hair.	Quill.	Horse's hoofs.	Scale of reptile.
Carbon, ...	50·89	50·89	51·09	50·14	52·43	50·40	53·60
Hydrogen, . . .	6·81	6·78	6·12	6·67	7·22	7·00	7·20
Nitrogen, ...	17·22	17·25	16·91	17·94	17·93	16·70	16·30
Oxygen and Sulphur,	25·63	25·08	25·88	25·25	22·42	25·90	22·90
	100·00	100·00	100·00	100·00	100·00	100·00	100·00

These substances have also this peculiarity, that, notwithstanding their great richness in organic matters, they are extremely slow to decompose.

Hair.—The only real point of interest connected with hair appears

to me to be the question as to what its various colors are to be ascribed, and I regret that here I can only give conjectures and not positive facts. Vauquelin and Fourcroy, who analyzed hair most carefully half a century ago, stated that hairs were hollow cylindrical tubes filled with oils of various colors; but Gmelin and others state that the coloration of hairs is due to the different proportions of sulphur that they contain.

QUANTITY OF SULPHUR IN HAIR.

Brown,	4·98
Black,	4·85
Red,	5·02
Grey,	4·03

Recently Mr. Barreswil has published a paper, in which he states that the coloration of hairs is probably due to the proportion of iron in their composition, and he argues that as iron is the essential element of the coloring matter of blood, it is highly probable that it fulfils the same office with respect to hair. I may state, *en passant*, that also great improvements have lately been made in dyeing human hair. Formerly the patient had to undergo most unpleasant treatment, his head being covered with a paste consisting of three parts of lime, and one of litharge. An oil cap was then applied and the patient left for twelve hours, when the disagreeable operation of removing the mass and clearing the hair was proceeded with. The black dye communicated to the hair in this process was due to the sulphur of the hair combining with the lead of litharge, and forming black sulphuret of lead. The present process consists in cleaning the hair thoroughly with a strong alkaline soap, or a little weak alkali, then carefully applying a solution of nitrate of silver, and lastly a solution of monosulphuret of sodium.

Wool differs from hair chiefly by its property of felting, which it owes to its numerous cross lines or serratures, as they are termed; the finer the wool the greater the number of its serratures. Thus, whilst Mr. Goss has found in the finest Saxony wool 2720 of these serratures in a single inch in length, he only found 2080 in an inch of South Down wool, and 1850 in Leicester. The wool of sheep can be classed under two heads, that is, into long wool and short wool. Certain classes of sheep will maintain the type or quality of their wool under every circumstance. Such are the original types of South Down, Norfolk, and Dorset, all of which are short wool, and all these sheep feed upon fine and short grass. It has been observed that if they are fed upon coarse grass, their wool will also become coarse. This is also true with Welsh, Scotch, and even Spanish merinos. A further proof that this view appears correct is, that the long-wool sheep, such as those of Leicester, Lincoln, and Kent, feed in valleys where grass is long and coarse, In all cases the size of the animal appears also to correspond with their class of food. Another curious fact is the facility with which one type of sheep will merge into another if they change food and climate. Thus many attempts have been made to introduce into France, our Leicester breed, the wool of

which is so remarkable for its fineness, length, and silvery appearance. Still, after four or five years residence there, the wool has lost its valuable qualities. In fact, they are no more the Leicester breed. The coarse wool of sheep, however, such as those of Devonshire, does not appear to be so rapidly influenced by any change of climate which the animal may undergo. The aptitude which various kinds of wool have for dyes is also very interesting. Thus the wool of one kind of sheep will not dye with the same facility as that of another; and wool dyes much more uniformly, if the animal has been washed before shearing than when the washing is performed upon the wool afterwards. Lastly, the wool removed by the liming process before described will be far inferior in dyeing properties to wool taken from the same kind of animal during life. It may be interesting to some present to know the best method of removing these irregularities. I was engaged during my assistantship at the Gobelins in investigating this matter, and I found that the best plan was to steep the wool for twenty-four hours in lime water, and then to pass them through weak hydrochloric acid. Wool, as it leaves the animal, is not fit for either dyeing or spinning. Thus, when wool is washed with water, it yields a large quantity and variety of substances, which in France bear the name of *suint*. The most interesting fact connected with this is, that the 15 per cent. yielded by wool does not contain, as shown by M. Chevreul, any salts of soda, but a large quantity of salts of potash, the greatest part of which is combined with an acid called sudoric; and what increases the interest of this fact is that Messrs. Maumené and Rogelet displayed at the last Exhibition salts of potash which they had obtained commercially from this new source. In fact they have established in several of the large manufacturing centres of France, where considerable quantities of wool are used, factories for the extraction of salts of potash from the *suint*, and they supplied the jury with the following particulars: That a fleece of wool weighing 8 lbs. yielded on the average about 1¼ lb. of dry suint, or sudorate of potash, and this would further yield about seven ounces of pure potash. If it is now considered that there is annually twenty million pounds of wool washed in Rheims, thirty millions at Elbeuf, and four millions at Fourmies, it would appear from this quantity that if it were all subjected to Messrs. Maumené and Rogelet's treatment, about 2½ million pounds of pure potash might be recoverable. For further details on this point see Dr. Hofmann's report on chemical products and processes in the last Exhibition. Wool which has been simply washed, as above described, is not sufficiently free from extraneous matters to be fit for application in manufactures. It is necessary that it should be scoured, for which purpose, on the Continent, it is allowed to remain for some time in putred urine, or weak ammoniacal liquor, but in this country it is placed in strong alkaline of soap, or soft soap passed through rollers to press out the excess of soap, together with the impurities which it removes, well washed, and dried. In these operations wool loses in weight above 50 per cent. when of good quality, and above 30 per cent. when inferior. But even then the wool still retains a certain amount of fatty matters, which it yields to hot alcohol.

The following table, published by M. Chevreul, will give you an idea of the composition of the wool dried (at 212°):

Earthy matters, ...	27·40
Organic and inorganic salts, soluble in water (*suint*),	32·74
Fatty matters, ...	8·37
Wool, ...	31·49
	100·00

Elementary composition, C. 50·66, H. 7·03, N. 17·74, O. 22·32, S. 2·25.

Before proceeding further, I should like to call your attention to the curious fact that the fatty matters of wool are completely different from the fatty matters of the animal itself; thus, whilst the ordinary suet will be saponified by an alkali, the fat of the wool will not undergo that change, the stearine and elearine being only converted into an emulsion. From experiments I have made, I am able to state that the common opinion, that the differences in quality observed in various wools are owing to their fatty matters, is erroneous, as the pure wool obtained as above yielded to the dyer colors as brilliant as those presented by wools in which a part of the fatty matter still remained. Another important fact connected with the composition of wool is the quantity of sulphur it contains, which does not appear to be part of the fibre, as the matter containing it can be removed by a weak alkali without destroying the fibrous appearance of the wool, although its tenacity is greatly impaired, and its power of taking dye considerably diminished. Another remarkable fact is that when wool is bleached by sulphurous acid, the only agent known which will effect that purpose, it becomes incapable of taking many colors, especially the new and brilliant coal tar dyes. The long-disputed question among chemists—how sulphurous acid operates so as to bleach wool?—has lately been solved by Messrs. Leuchs and Weber, who have proved that sulphurous acid unites with the coloring matter of the wool, forming a colorless compound, in proof of which it appears that if the wool is placed in boiling water this colorless compound is dissolved, and the wool regains its susceptibility to dyes, though it is slightly discolored. A slight amount of alkali added to the boiling water greatly facilitates the removal of this artificial sulphuretted compound. In a paper lately published by Mr. Grothe, he states that 100 parts of wool fix, on an average, 0·67 of sulphur, or 1·31 of sulphurous acid to bleach it, and, practically, 100 parts of wool require about five parts sulphur to be burnt to produce the result. I should also state that wool must always be wet before being submitted to the fumes of sulphur, and it is always advantageous to pass it previously through a soap lye or weak alkali. Wool so bleached should always be well washed in cold water to remove the excess of sulphurous acid, which otherwise, if the wool were subsequently exposed to moisture, might be converted into sulphuric acid, and destroy the fibre of the wool. It may be interesting to ladies to know the process used by a French scourer, named Jolly, to restore Cashmere shawls discolored by time. It consists in dipping them in a solution of sulphurous acid, which

bleaches the wool, but does not affect the fast colors with which the fibres composing the patterns of the shawls are dyed. The shawls then only require to be washed and pressed to be restored to their original beauty. There is no doubt in my mind that a solution of sulphurous acid might be substituted for the gas in bleaching wool with advantage and economy, owing to the sulphurous acid being in a more condensed form, and in better condition for effecting the bleaching process. A few years ago I took advantage of the fact that wool contains sulphur to produce upon it an artificial lustre. The woolen goods were passed through a weak boiling solution of acetate of lead, washed carefully in pure water, and submitted to the action of high-pressure steam, when the lead combined with the sulphur of the wool, producing galena, which gave the wool a lustre. The action was regulated by generating, under the influence of steam, nascent sulphuretted hydrogen from a polysulphuret of sodium, which facilitated the object in view. Wool is generally dyed either in the fleece, after undergoing the processes of washing and scouring, or it is first spun into yarn or worsted. To describe all the various methods of dyeing wool would far exceed the limits of this lecture. The operations of spinning wool into yarn or worsted are purely mechanical, and it is not therefore within my province to describe them. The same remark applies also to the manufacture of felt and shoddy, now so extensively carried on in Yorkshire, and I shall therefore merely refer to one or two points having reference to chemistry, such, for instance, as the working up of the wool or the cotton in worn-out fabrics. To recover the wool from such fabrics the process is most simple, consisting simply in immersing them in diluted muriatic acid, and drying them at a temperature of about 220°, by which means the cotton is completely destroyed, the wool remaining unaffected. The material is then submitted to the action of a "devil," which separates and blows away the cotton, leaving the wool ready for being worked up. To remove the vegetable fibre with the view of applying it to the purposes for which it is adapted,—as the paper manufacture, for instance,—the following process has been devised by Mr. F. O. Ward and Captain Wynants. The mixed fabric is submitted to high-pressure steam (60 to 80 lbs. to the square inch), and under the influence of this high and moist temperature the vegetable fibre remains unchanged, whilst the animal one is so much disorganized that when the rags are removed from the receptacle and dried, and submitted to the action of a bathing machine, the cotton fibre remains intact, whilst the animal matter falls to the bottom of the machine in the form of a dark colored powder mixed with small lumps of the same substance; this residue has been advantageously applied as a manure, by these gentlemen, under the name of "ulmate of ammonia." I am happy to state that chemical science has discovered several means of distinguishing cotton from wool when employed in the same fabric, and even of determining their respective weights in the same; but the aid of the magnifying powers of the microscope is often required in investigating the mixtures of wool with flax, cotton, jute, &c., which are now so extensively and so ingeniously

spun together. The description of these processes, however, would involve so much technicality, and require so much time, that I must not trouble you with their details. The same remarks apply to the means used for distinguishing the materials used in mixed fabrics of silk and cotton, or silk, wool, and cotton.

Silk.—This material has always been highly esteemed, owing to its remarkable durability, and to the beauty of the fabrics produced from it. Thus, the Chinese have used silk from time immemorial, and the Romans held it in such high estimation, that, at the time of the Cæsars, silk was worth its weight in gold. The most interesting fact for us is the introduction of the silkworm into Europe; it is related that in A.D. 555, two monks, returning from the East, concealed some silkworms' eggs in their staves, and having succeeded in rearing the worms, their culture soon spread through Greece and Turkey, and gradually found its way into Italy towards the twelfth century. The silk in use at the present day is chiefly derived from the *Bombyx mori*, but the extensive disease which has, during the last eight or ten years, destroyed very large numbers of the worms, has given rise to great efforts to introduce some new species, two of which, the *Bombyx mylitta*, feeding on the *l'alma christi* or castor-oil tree, and the *Bombyx alianthus*, feeding on the plant from which it is named, have been to some extent successful. The material forming the silk is secreted in two glands placed upon the side of the animal's body, whence it passes into an organ called spinaret, on each side of which are two other glands, which secrete a gummy substance, and this uniting with the former forms the silk fibre. Permit me to add here a fact which I think will interest you—viz., the extraordinary weight of silk which a small weight of eggs will yield. Thus, four ounces of eggs will yield 87,900 to 117,000 cocoons; and as, on an average, a pound of silk requires 270 cocoons, the four ounces of eggs will give 422 lbs. of silk, or 100 lbs. of cocoons yield generally 8 lbs., or about 14 per cent. of silk. The production of silk fibre from cocoons is extremely simple. It is effected by placing the cocoons in boiling water which softens or dissolves the gummy matter which binds the fibres together, and the ends of the fibre being detached and placed on a reel, is easily wound. This is the state in which it is usually imported in this country under the name of raw silk. When two or more of these fibres are slightly twisted together they form what it is called tram or weft, and when two of the threads are twisted in opposite directions and laid together they form organzine or warp. To render this substance susceptible of dyeing, it is necessary to remove the gum by an operation called boiling off, which consists simply in boiling the silk for some time in a soap lye, and washing and wringing it well afterwards, in which operation it loses about 21 per cent. The following table will show the chemical composition of silk:

Gelatine, ...	19·08	Commercial yield, 79 per cent. of silk.
Albumen, ...	25·47	
Wax and fatty substances, .	1·45	
Silk fibre, ...	54·00	
	100·00	

Fibroine.—Carbon, 48·53; hydrogen, 6·50; nitrogen, 17·35; oxygen and sulphur, 27·62.

Conditioning Silk.—This expression implies the ascertaining of the real commercial value of silk, or, in other words, its condition, and the necessity of this has been so fully admitted that a conditioning house has existed for 40 or 50 years in Lyons, and its advantages have been so fully appreciated that similar establishments have arisen and are well supported in every town on the Continent, where dealings in silk to any amount take place. I may mention, as an instance of the universal adoption of the practice, that even in Crefeld the finest building in the town is the conditioning house. The result is that on the Continent the intervention of the conditioning house between buyer and seller has become quite a matter of course, with the happy result of abolishing a class of dishonorable dealing which is eating like a canker into the silk trade of Great Britain. I cannot understand why the attempts made to introduce this admirable system into our country have hitherto met with so little success, and can only infer that there is an unsoundness in the trade, which places many of the silk manufacturers to a great extent under the control of wealthy merchants, who, it appears, are the chief opponents of conditioning. Otherwise one would suppose that its advantages to all engaged in working up this valuable product are too obvious to require demonstration, for, taking the most lenient view of the matter, the average gain to the manufacturer by conditioning will be not less than five per cent., and this loss (if he does not condition) cannot be recovered in any subsequent stage, so that his foreign competitor has in this respect alone an advantage over him of at least five per cent. Allow me to conclude this lecture by stating in a few words how conditioning is carried on. Silk being an exceedingly hygrometric substance—its moisture varying constantly with the amount of humidity and the temperature of the atmosphere—the first operation is to ascertain the total amount of water it contains, for which purpose samples, carefully selected from the bale when it reaches the conditioning house, are weighed in delicate scales, dried in hot-air stoves, and re-weighed, the excess of moisture (beyond the 10 per cent. admitted to be the average normal quantity) being then easily calculated. The second operation carried out in the conditioning house is that of boiling off the samples dried as above, and again drying and re-weighing, to ascertain the quantity of soap, oil, sugar, acetate of lead, &c., added to give weight, and the result of this operation is to show a loss of 30, 35, and even 40 per cent. instead of about 21 per cent., which is the average amount of natural gum.

(To be continued.)

On the Revivification of Animal Charcoal. By Henry Medlock, Ph.D., F.C.S., M.P.S.

From the London Chemical News, 272.

The principal source of expense in a sugar refinery is that of animal charcoal, and it is a great desideratum to the refiner, commencing with

the use of new animal black, to adopt a means of keeping his coal in good condition, and retaining unimpaired its decolorizing powers after each successive use. I will treat the subject very briefly under the following heads:

1st. The composition of bone and animal charcoal.

2d. Its decolorizing property, and the causes of its becoming inactive.

3d. The means of restoring its primitive powers of absorption and decolorization.

I. The Composition of Bone and Animal Charcoal.—Bone, as is well known to anatomists, is a solid structure composed principally of phosphate of lime and osseine, a modified form of gelatine. The phosphate of lime, or solid portion of the bone, is composed of an infinite number of minute, almost microscopic cells, which are filled up by osseine, and bound thereby, as with a cement, into a solid mass.

The composition of bone, after the removal of adhering fat by boiling, is as follows:

Phosphate of lime,	63·1 per cent.
Carbonate of lime,	1·4 "
Phosphate of magnesia,	2·1 "
Other salts,	2·4 "
Osseine,	31·0 "
	100·0

When submitted to heat in a closed vessel, to which air cannot gain access, the osseine is decomposed, evolving oily and ammoniacal products, which are, by suitable arrangements, collected and applied to many useful and economical purposes. In the retort remains the cellular structure of the bone in a most porous condition, each cell and pore being coated with a thin film of finely divided carbon, resulting from the decomposition of the organic osseine.

The purely chemical reasons why the porous animal charcoal should possess such extraordinary decolorizing and general absorptive properties, is a question I need not now enter into, but I shall do so fully in a forthcoming pamphlet.

II. The Decolorizing Properties of Animal Charcoal, and the Causes of its becoming Inactive.—It is well known to the refiner that his charcoal too soon loses the power of decolorizing his syrups, and the question arises, what is this owing to? It is *à priori* assumed that it is owing to the grains of coal becoming coated on the surface with the slimy albuminous and mucilaginous matters contained in the raw sugar, which destroy to a great extent its porosity. This is doubtlessly one cause, but the principal and by far the most serious cause is the presence of lime in the raw sugar, and which in a short time effectually chokes up the pores, and in the process of reburning cannot be removed, although the mucilaginous materials are destroyed.

III. The means of Restoring its Primary Powers of Absorption and Decolorization.—When the charcoal ceases to decolorize, it is usually washed with hot water to remove the syrup remaining therein, and then reburned in closed furnaces of various construction, the object of reburning being to carbonize the coloring matters extracted from

the syrups. This restores to some extent the decolorizing powers of the charcoal; but at each successive reburning the coal continues to lose its properties, and at last ceases altogether to act as a decolorizer, unless it be mixed after each reburning with a certain portion of new charcoal.

Another process, and one frequently adopted, is to destroy the organic matters by keeping the charcoal in water and allowing it to ferment for several days, draining off the water, and adding fresh water containing about $\frac{1}{4}$ to $\frac{1}{2}$ per cent. of hydrochloric acid. The little acetic acid formed, and the hydrochloric acid added, dissolve a small quantity of lime, and so far act beneficially. But the good effect is more than neutralized by the fact of the acids attacking the structure of the bone itself, namely, the phosphate of lime, thus rendering the coal friable, and consequently making much dust and waste.

Having referred to the two methods in common use of revivifying the decolorizing powers of charcoal, and alluded to their inutility and defects, I will describe a new method, as simple as it is ingenious, of rendering old and comparatively useless charcoal as good, and, indeed, better than new. Corenwinder, an eminent German chemist, has, by numerous experiments, established the following axiom, namely:

"That the decolorizing power of charcoal used in sugar refining is correlative to its power of absorbing lime."

In other words, the more the pores of the coal become choked up with lime, the less is its power of decolorizing. Now, to remove the obnoxious lime without attacking the structure of the bone itself, is a question which has occupied for many years the ingenious mind of my friend, Edward Beanes, C.E, F.C.S.

Mr. Beanes, who, by his chemical researches on the sugar plantations of Cuba, has enabled the planters not only to produce much finer qualities of sugar, but considerably to augment their produce, has recently patented a process of restoring to charcoal its primitive properties of decolorizing syrups. Mr. Beanes found that charcoal perfectly dry and hot absorbs dry hydrochloric gas with the greatest avidity and in enormous quantity. The gas combines with the lime and converts it into soluble chloride of calcium. After the charcoal has been treated with gas, a portion of untreated charcoal is mixed up with it; the uncombined gas remaining in the pores of the former is taken up by the latter, and the whole becomes neutral; the chloride of calcium is then washed out—requiring only a few hours—and the charcoal is afterwards burned in the usual way. It is then found that the decolorizing power of the charcoal is augmented at least 100 per cent.

The advantages of Mr. Beanes' process are as follows:

1st. It removes the whole of the lime and carbonate of lime from the pores without attacking the phosphate.

2d. It augments the decolorizing powers of the coal upwards of 100 per cent.

3d. It requires no expensive apparatus, and the process is almost costless, two saleable products being obtained nearly equal in value to the materials employed.

I have thus ventured to introduce Mr. Beanes' process to the notice of English refiners, not simply from feelings of personal friendship, but from the firm conviction that by its general adoption, he will confer as great a benefit on his own countrymen as he has already conferred upon the sugar manufacturers of Cuba.

Chemical Laboratory, 20, Great Marlborough Street, London, W.

For the Journal of the Franklin Institute.

Notes of Shipbuilding and the Construction of Machinery in New York and vicinity.

The Steamer Sacramento.—Hull built by Wm. H. Webb, New York. Machinery constructed by Novelty Iron Works. Superintendent of construction, Captain Francis Skiddy. Route of Service, San Francisco to Panama. Owners, Pacific Mail Steamship Company.

Hull.—Length on deck, 304 feet. Breadth of beam, 42 feet 6 inches. Depth of hold, 28 feet 6 inches. Number of decks, 3 full and orlops. Draft of water, 16 feet. Frames, molded, 16 inches, sided, 14 to 20 inches, apart at centres, 36 inches. Three water-tight bulkheads. Rig, brig. Tonnage, 26 7, O. M.

Engine.—Vertical beam. Diameter of cylinder, 100 inches. Length of stroke of piston, 12 feet. Is fitted with Sewell's condenser.

Boilers..—Four, tubular. No blowers to furnaces.

Water-wheels.—Diameter, 27 feet. Material, iron.

REMARKS.—The *Sacramento* is built of white oak, chestnut, hacmetac, &c., the principal pieces being of live oak. She is filled in solid. Her fastenings are of copper and iron. She is strapped with iron straps diagonally and double laid, $4\frac{1}{2}$ by $\frac{7}{8}$-inches. Under her spar-deck are 280 knees, main-deck, 240, berth deck, 222, and orlops, 80, making in all 822 knees. Her water-ways are of yellow and white pine. This vessel embraces all the modern improvements for securing great strength, safety, and comfort. Proper ventilation is looked to in this vessel, the state rooms being very large, and lattice work secured in every position to insure a full and free circulation of the air in all the apartments.

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The Steamer Euterpe.—Hull built by C. H. Mallory, Mystic, Connecticut. Machinery constructed by C. H. DeLamater, New York. Route of service, New York to Wilmington, N. C. Owner, C. H. Mallory.

Hull.—Length on deck, 176 feet 6 inches. Breadth of beam, 31 feet. Depth of hold, 10 feet 6 inches. Depth to spar-deck, 17 feet 6 inches. Number of decks, 2. Draft of water, 12 feet. Frames, molded, $12\frac{1}{2}$ inches, sided, 8 inches, apart at centres, 26 inches. No bulkheads. Rig, foretopsail schooner. Tonnage, 799, O. M.

Engines.—Vertical direct. Diameter of cylinders, 26 inches. Length of stroke of piston, 2 feet 6 inches.

Boilers.—One, tubular. Located in hold. Length, 16 feet 6 inches. Width, 13 feet. No blowers to furnaces.

Propeller.—Diameter, 9 feet 6 inches. Material, iron.

REMARKS.—This vessel is of white oak, chestnut, and cedar, and is

square fastened with copper and iron. She has a full set of knees under both decks, and her floors are filled in solid. Her engine department is furnished with an independent steam fire and bilge pump, bilge injections, &c.

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The Steamer Electra.—Hull built by Van Deusen Bros., New York. Machinery constructed by Etna Iron Works, New York. Route of service, New York to Providence, Rhode Island. Owners, Neptune Steamship Company.

Hull.—Length on deck, 245 feet. Breadth of beam, 40 feet. Depth of hold, 15 feet 6 inches. Draft of water, 10 feet. Frames, molded, 18 inches, sided, 7 inches, apart at centres, 24 inches. Four athwartship bulkheads. Rig, none. Tonnage, 1442 tons, O. M.

Engines.—Vertical direct. Diameter of cylinders, 44 inches. Length of stroke of piston, 3 feet.

Boilers.—Two, tubular. Located in hold. No blowers to furnaces.

Propeller.—Diameter, 13 feet. Material, cast iron.

REMARKS.—The floors of this vessel are filled in solid for 100 feet. She is of white oak, chestnut, and hacmetac, and square fastened with copper and treenails. Her bottom plank is of oak, 3½ inches thick. Wooden straps extend around the frame of the vessel. Her deck extends over the sides of the hull 9 feet and is sponsoned. The *Electra* is a fine vessel, built in the best manner, and gives satisfaction on her route of service. The steamer *Galatea*, of same line and constructed at the same time, is a sister ship.

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The Steamer Ariadne.—Hull built and vessel owned by Charles H. Mallory, Mystic, Connecticut. Machinery constructed by C. H. DeLamater, New York. Route of service, New York to Wilmington, North Carolina.

Hull.—Length on deck, 183 feet. Breadth of beam, 34 feet. Depth of hold, 22 feet. Number of decks, 3. Draft of water 13 feet. Frames, molded, 12½ inches, sided, 10 inches, apart at centres, 26 inches. Rig, brigantine. Tonnage, 779 tons. O. M.

Engines.—Horizontal. Diameter of cylinders, 26 inches. Length of stroke of piston, 2 feet 6 inches.

Boiler.—One, tubular. Located in hold. Length, 16 feet. Width, 11 feet. No blowers to furnaces.

Propeller.—Diameter, 12 feet. Material, cast iron.

REMARKS.—This vessel is of white oak, chestnut, and cedar, and is square fastened with copper and treenails. Her floors are filled in solid. Under each beam beneath the two lower decks there are six knees, and under upper deck hanging knees every six feet, with lodging knees abreast of hatches. She is supplied with pumps, injections, &c., and is a well built steamer.

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The Steamer Granada.—Hull built by Thomas Stack Williamsburgh, L. I. Machinery constructed by Fulton Iron Works, New York. Route of Service, New York to Charleston, S. C. Owners, Arthur Leary and others.

Hull.—Length on deck, 181 feet. Breadth of beam, 29 feet 10 inches. Depth of hold, 26 feet 3 inches. No of decks, 3. Draft of water, 16 feet. Frames, molded, 12½ inches, sided, 8 to 10 inches, apart at centres, 26 inches. Rig, brig. Tonnage, 762 tons, O. M.

Engine.—Vertical direct. Diameter of cylinder, 44 inches. Length of stroke of piston, 2 feet 9 inches.

Boilers.—Two, tubular. Located in hold. No blowers to furnaces.

Propeller.—Diameter, 11 feet. Material, cast iron.

REMARKS.—This steamer is of white oak, chestnut, and hacmetac, and square fastened with copper and treenails. Has knees to each beam under deck. Bottom planks of white oak. Pilot house and officers' quarters on deck. The *Granada* is well constructed, well fitted, and will be a safe and useful vessel on her route of service. The steamer *Alhambra*, built at the same time, and owned by the same firm as the *Granada*, is a sister vessel.

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The Steamer Cotopaxi.—Hull built by C. & R. Poillen, Williamsburgh, L. I. Machinery constructed by C. H. DeLamater, New York. Owners, Brazilian Government.

Hull.—Length on deck, 198 feet, 6 inches. Breadth of beam, 33 feet 6 inches. Depth of hold, 17 feet 6 inches. Draft of water, 13 feet. Frames, molded, 13 inches, sided, 8 and 9 inches, apart at centres, 26 inches. Rig, brigantine. Tonnage, 1054 tons, O. M.

Engine.—Vertical direct. Diameter of cylinders, 54 inches. Length of stroke of piston, 4 feet 4 inches.

Boilers.—Two, tubular. Located in hold. Use blowers to furnaces.

Propeller.—Diameter, 13 feet 4 inches. Material, cast iron.

REMARKS.—This vessel is of white oak, hacmetac, &c, and is fastened in the securest manner with copper, treenails, &c. Around her frames iron straps diagonally and double laid, 4 by ⅝-inches, extend, adding to her strength. This vessel, owing to her admirable construction, speed, &c., was recently sold to the Emperor of Brazil, to be fitted and used as a gun-boat. That she will fulfil the sanguine expectations of both her builders and owners, not the least doubt exists.

E. M. B.

New York, May 25, 1865.

On the Use of Petroleum as Steam Fuel. By C. J. RICHARDSON.

From the London Chemical News, No. 269.

As the patentee of the mode for burning petroleum as steam fuel, now being experimented upon at Woolwich Dockyard, permit me to reply to the article by Mr. Paul, which appeared in the *Chemical News*, of December 17 last. (See *Jour. Frank. Inst.*, vol. xlix, p. 130.)

The relative heating powers of petroleum and coal as depending upon their chemical composition is not the question; the ability of each to create steam is the real matter to be considered.

Petroleum as steam fuel can be very nearly fully utilized; it produces no ash, submits to mechanical management, and makes little or no smoke, does not require any strong draft or current of air like coal, which will not burn without it; and the consequence of which is, a very considerable portion of the fuel is lost as waste heat in the chimney.

In a late work by Mr. Wye Williams, one of our chief authorities on this subject, entitled "On the Steam Generating Power of Marine and Locomotive Boilers," he details three careful experiments as to the best form of boiler to obtain the greatest amount of heat from coal. He gives the temperature of the waste heat in the first experiment as 1060°; to the second, 760°; and the third, 635°—and this, be it observed, with the consumption of only 3½ cwt. of coal to each experiment. I should like to learn the temperature of the waste heat in the chimney of a furnace burning from twenty to thirty tons of coal per day. We know the current is so strong that it often carries up small coal and cinders along with it; that the heated gases often take fire by a spark from the furnace, and burn at the top of the funnel with a fierceness almost equaling the flame from a blast furnace. Is this flame or waste heat employed in creating steam? and how much is the coal utilized? In practice, the ratio of the heating power of petroleum and coal is about $=1{\cdot}4=0{\cdot}4$. We shall never learn the wicked waste we are making of our coal until petroleum supersedes it.

The American plan can be seen by inspecting the French patent; it was not likely to be successful; it does not follow that other more simple methods may not succeed.

My grate, which burns petroleum through a porous material, has has in every instance, when put under a boiler, proved petroleum to be full five times more powerful than coal for steam purposes—one ton doing as much as five tons of coal. If four tons out of five are saved for freight space, the price of the latter being 7*l.* per ton, the profit on every ton of petroleum would be 14*l.* 15s.,—the coal at 15s., the petroleum at 17*l.* per ton.

But a shipowner might not select the American crude at 17*l.*; he would take the Flintshire coal oil, quite as good for his purpose; this is only about 10*l.* per ton.

The average price of coal on a long voyage would be low at 2*l.* per ton. Taking these prices and freights at the reduced price of 5*l.* per ton, in a ship requiring 500 tons of coal, and using instead 100 tons of petroleum, would gain by the exchange 2000*l.* It would not be necessary to start with the full quantity of petroleum, it being more distributed about the earth than coal, obtainable at first cost in the oil countries.

As to the alleged advantage of the oil taking up less room than coal, no notice need be taken of it; a great deal more might be said of the advantage of a ship being able to go from port to port without turning aside for fuel.

Now, as to the highly dangerous, inflammable nature of petroleum, this is in a very great part fudge. If the oil were contained in cast iron cases securely closed, no vapor could escape; or if the small amount of spirit which produces the inflammable vapor was first extracted, the residue, the burning oil and heavy petroleum, would be no more dangerous than so much lard or spermaceti.

Use of Petroleum or Mineral Oil as Steam Fuel in place of Coal.

By B. H. Paul.

From the London Chemical News, No. 271.

This subject continues to excite so much interest among those connected with steam navigation, and the statements which have been made by those who propose by means of petroleum or coal oil to effect a reorganization of our naval and mercantile marine, are so totally irreconcilable with all known principles relating to the application of fuel, that it will not be superfluous to illustrate this fact by reference to the opinions expressed and to the arguments used by several of the speakers in a recent discussion of the subject at the United Service Institution. Such a course is the more admissible since many who appreciate the importance of any mode of improving or economizing the use of fuel, confess their inability to judge as to the merits of this project, and express themselves desirous of information.

The data which I have already referred to in this journal,* for the purpose of showing that the substitution of petroleum for coal as fuel is impracticable, are not disputed. On the contrary, they are adopted by those who advocate this change. But, at the same time, they urge that those data relate only to a theoretical consideration of the subject, and are therefore not to be taken as deciding the practical question as to the relative fuel value of petroleum and of coal. In this opinion I quite concur, but it must be remembered that no means of arriving at a practical solution of this question have yet been afforded. It was only from the want of such positive data, expressing results obtained with petroleum and with coal, as would enable an engineer, or any one else, to form an opinion as to the comparative values of these materials as fuel for steam vessels, that I was constrained to have recourse to the only accessible criterion by which an opinion could be formed as to the representations which have been made. The comparison of the utmost effects capable of being produced by petroleum and by coal under the most favorable conditions, is perfectly valid so far as it applies; but I must admit that it would have been far more satisfactory to have been able to base my opinion on the results of trustworthy experiments made with the object of ascertaining the actual duty obtained with the two materials, and I cannot refrain from expressing my surprise that statements so extraordinary as those I have referred to, should have been put forward ostensibly as the result of experiments made in the government dockyard, with the apparent authority they thus acquire, and without a vestige of practical evidence in support of them. Mr. Richardson has publicly declared that forty-two gallons of oil equal one ton of coal in steam-producing power. He admits that this requires proof, and he has promised that it shall be proved;† but as yet the proof has not been furnished, nor was any approach made towards it in the papers read at the United Service Institution, on the 16th inst. It rests, therefore, with the advocates for the use

* *Chemical News*, December 17, 1864, page 292.

† *Mining Journal*, December 24, 1864, page 890.

of petroleum to remove the cause of the objection they made to the comparison between that material and coal upon theoretical grounds.

But their chief argument in favor of petroleum is, that this material can be used as fuel so that its capability may be rendered effective to a much greater proportion than is possible in the case of coal. Here again we are without any evidence of a practical nature in support of this proposition. No doubt it is a well established fact that different kinds of fuel do not always admit of equal effects being produced in generating steam, although their heating capability or calorific power may be the same. It is upon this ground that the advocates of petroleum take their stand, and Mr. Richardson states that, while one-half of the coal consumed in a marine boiler furnace disappears and is lost as soot and smoke, the heating capability of petroleum is fully utilized.* If this were admitted, we should still be far from attaining that advantage from the use of petroleum in place of coal which Mr. Richardson represents by stating that one ton of petroleum equal five tons of coal; for, since the calorific power of petroleum is to that of coal as 1·5 : 1, it follows that by fully realizing the calorific power of petroleum and realizing only half that of coal, the practical effects of these materials would be in the ratio of 3 : 1, not as 5 : 1, which, upon the same supposition, would require the calorific power of petroleum to be 2·5 as compared with that of coal = 1·0. There is, therefore, some error in this; but without attempting to ascertain in what it consists, it will be more useful to inquire how far there may be—in the absence of those special data which are so much needed—any means of instituting a practical comparison between coal and petroleum in regard to the possibility of using the latter more advantageously than coal as fuel in a marine boiler furnace.

It is well known that no kind of fuel is burnt under ordinary circumstances, so as to realize the whole of the heating effect it may be capable of producing. Therefore the true practicable comparison between different kinds of fuel as regards their value, consists in ascertaining not only what they respectively can do, but more especially what they really do. The actual work done by fuel depends partly upon its nature, partly also upon the kind of effect to be produced. When an intense degree of heat or very high temperature is required, as in smelting iron, the heating capability really utilized is not a tithe of that which is utilized when fuel is burnt for generating steam, and still less than that utilized when fuel is burnt in a common domestic grate.

But even in the generation of steam, different kinds of fuel give different results, and under the very unfavorable conditions which obtain in a marine boiler furnace, experience has shown that there is a great difference in the duty or effects produced by equal quantities of different coal possessing equal heating capabilities. Hence the recognised practical superiority of Welsh steam coal over the more bituminous kinds of coal represented by the North country coal.

Now, what is the difference between these two kinds of coal to which

* See *Times*, December 14, 1864, page 7.

their different value as steam fuel is referable? It is simply this, the Welsh coal is almost entirely fixed, approximating, in this respect, to pure carbon; it does not give out much combustible gas when heated, but it burns almost entirely within the furnace, and, unless the rate of combustion be very rapid, it burns completely, generating its full equivalent of heat, which is transferred through the medium of the combustion products to the water in the boilers. The amount of heat generated by the combustion of the best Welsh coal is equivalent to the production of nearly 15 lbs. of steam from water at 212° F. for each pound of the coal completely burnt. Of course, this duty is never realized in practice, because the water has to be heated to the boiling point, and because the whole of the heat generated cannot be transferred to the water in the boiler, great part of it escaping in the combustion products. But the approximation to that theoretical duty will be greater in proportion to the perfect combustion of the coal, and to the absence of soot or smoke production. For every pound of soot or smoke produced, the possibility of generating at least seven pounds of steam will be lost, and the duty of the coal will be proportionately reduced.

The calorific power of the best bituminous coal is not appreciably less than that of Welsh steam coal, but it contains from 30 to 40 per cent. of volatilizable substance, and consequently when heated combustible gas or vapor is evolved to that extent. This gas or vapor, amounting to something like 300 times the volume of the coal from which it is produced, mixes with the combustion products, and is thereby rendered less readily combustible. Under the influence of the draught, and by reason of its great bulk and mobility, it is drawn out of the furnace before it can be burnt, and, passing into the tubes of the boiler, the combustion is stopped partly by the cooling of the gas, and partly by the want of air, so that instead of generating its equivalent of heat it produces soot and smoke.

This action takes place to some extent with all coals, especially when it is burnt under the unfavorable conditions obtaining in a marine boiler furnace, and it was the disregard of this circumstance which vitiated the results of the long and costly experiments made some years ago by Dr. Lyon Playfair, with the view of ascertaining the relative value of different kinds of coal as fuel. But in regard to steam navigation, the relative values of different coals are determined by the degree to which this action takes place. The more a coal is capable of being burnt within the furnace, the better it is for that purpose. The greater the amount of volatilizable substance it contains, the less suitable it is, and the greater the extent to which production of soot and smoke is substituted for the production of heat. These being correlative results, it follows that the fitness of coal for steam navigation is inversely proportionate to the amount of volatilizable substance it contains. It is for this reason that while the duty obtained with Welsh coal sometimes exceeds 10 lbs. of steam per pound of coal burnt, that obtained with Newcastle coal is often as low as 6 or 7 lbs.

Applying this result of long experience to the case of petroleum as

compared with coal, the conclusion to which it leads is even more disadvantageous for the former than the comparison already made on the ground of calorific power and cost.* For petroleum is altogether volatilisable, and is, consequently, peculiarly liable to produce soot and smoke when burnt even slowly, and without any of those disadvantages to which it would be subject in the furnace of a marine boiler. Indeed, it appears to me that nothing can be more incompatible with the use of petroleum as fuel than the conditions which obtain in that case. No doubt it may be urged in answer to this that the introduction of a peculiar boiler is contemplated; but nothing need be said as to that contingency until the superiority of petroleum over coal shall have been satisfactorily made out.

The objection I have urged to the use of petroleum on the score of cost, has been answered by Capt. Selwyn, who suggests that the price of petroleum ought to be reduced if it came to be used as fuel, and that if it were not he believes a material almost identical with it may be obtained from coal at a lower cost, 9*l.* or 10*l.* per ton. So far as the price of petroleum is concerned, I am disposed to consider any anticipation of a reduction as being extremely delusive, and the lower cost of coal oil would still leave it at a great disadvantage as compared with coal.

But if Capt. Selwyn, before assuming the part of a protecting ægis to a deluded inventor, had applied to his own conceptions that simple axiom, that "a whole is greater than its part," he would probably have seen a little more clearly the value of the whole project of reorganization which it is proposed to carry out in relation to steam navigation. Thus, for instance, the very richest oil-yielding coal known—the Leeswood cannel—yields about one-third its weight of oil. In producing a ton of oil from three tons of this coal, a considerable quantity of combustible gas, capable of generating a large quantity of heat, is lost, and there remains greater part of the carbon of the coal in the state of coke, amounting to more than one ton. Both the gas and the coke are of value as fuel, so that the real fuel value of the oil from three tons of coal is, in fact, equal to the total fuel value of that quantity of coal *minus* the fuel value of the coke and gas. But according to the representations made in favor of substituting coal oil for coal as fuel, one ton of oil is to do the work of five tons of coal; so that, according to this view, the fraction of the heating power belonging to the three tons of coal will be equal to the heating power of five tons of coal!! This is equivalent to the proposition that part of three is equal to five, an absurdity so glaring that it is truly wonderful that it should have escaped recognition even by an inventor.

The signal misconception which characterises the views of those who advocate the substitution of petroleum for coal in steam navigation, was illustrated in an almost equal degree during the discussion following the papers read by Captain Selwyn and Mr. Richardson at the United Service Institution. Thus, for example, Sir Edward Belcher referred to the oxyhydrogen flames as proving the fuel value of hydro-

* See *Chemical News*, December 17, 1864, page 292.

gen to be much greater than that of carbon or of coal. Nothing could possibly be more irrelevant, and it can only be inferred that Sir Edward Belcher is not aware that the thermal efficacy of the oxyhydrogen flame is solely due to the fact that oxygen gas is used in the place of air for the combustion. This circumstance alone places the oxyhydrogen flame beyond the range of a practical consideration of the subject; but so far as a comparison can be instituted between hydrogen and carbon when burnt with oxygen, the fact is, that the thermal effect or temperature produced by carbon under that condition is far greater than that produced by an equal weight of hydrogen, these effects being in the ratio of about 10 : 7. When those substances are burnt in air, the difference in thermal effect is inappreciable. So far as the possible evaporative effect is concerned, the difference between petroleum and coal, in the amount of hydrogen they contain, is not so great as to have a very great influence; and since an increase in the amount of hydrogen in fuel is accompanied by increased liability to produce smoke and soot, it would, under existing circumstances, be rather a disadvantage than otherwise. Captain Selwyn's reference to the common fishtail gas burner used for illuminating purposes, and to the Bunsen burner, used in laboratories for heatings, as being illustrative of the different effects obtainable by burning combustible substances under different conditions, was equally infelicitous, and indicated an equal ignorance of the most rudimentary principles affecting the use of fuel; for in the flame of the fishtail burner, and in that of the Bunsen burner, the heating effects produced are equal for equal quantities of gas burnt, and the thermal effects or temperatures produced are probably little if at all different. Both these gentlemen appear to be very much "at sea" in their notions respecting fuel and its applications.

The view of this subject which was put forward in the above remarks will doubtless appear to many extremely trite and self-evident; but the fact that it is not so to every one interested in the use of fuel may perhaps be a sufficient excuse for stating it so fully, and the still more remarkable fact that some who have held such a view have been induced to abandon it, and to express themselves satisfied with the astonishing statements made as to the effects of petroleum when used as fuel, will show what strange results may be produced by vigorous assertion even of the most palpable absurdities. In fact, the whole of the arguments brought forward by those who contemplate effecting the entire reorganization of our navy, and of steam navigation, indicate a woeful deficiency of acquaintance with the subject, and well illustrate the proverbial danger of a "little knowledge."

There is, however, still room to hope that, by having recourse to that practical mode of deciding any question there may be in their minds as to the relative values of coal and petroleum, which I fully agree with them in thinking the only satisfactory test, and which is, unfortunately, a great desideratum in the present case, they will arrive at such a state of disillusion as will permit them to make a more useful application of their ingenuity.

The Steamship "City of New York."

The following is an abstract of a late voyage of this steamer from Liverpool, *via* Queenstown, to New York:

Wednesday, July 19, 1865.—Wind S. W.; Draft of water forward, 19 ft. 6 ins., aft, 20 ft. 10 ins.; 4·50 P. M. proceeded; 5·03 rock; 5·25 stopped; 6·28 took in tow by tender; 8·15 bell buoy; 8·25 tender left; ahead full speed.

Thursday, July 20.—Wind S. W. S. S. W.; 1·05 A. M. south stack; 4·15 slowed; 4·27 full speed; 9·25 Tinkar; 4·33 P. M. Roche's Point; 5·03 anchored; draft 19 ft. forward, 20 ft. 6 ins. aft; 7·15 proceeded; draft 19 ft. 3 ins. forward, 20 ft. 8 ins. aft; 7·38 passed Roche's Point.

Friday, July 21.—Wind W.; 135 miles; lat. 51·30, long. 13·16; 12·23 A. M. Fastnett; strong breeze and squally.

Saturday, July 22.—Wind N. W. W. N. W.; course N. 87 W.; 273 miles; lat. 51·42, long. 20·29; fresh breeze and cloudy.

Sunday, July 23.—Wind N. W. by W.; course S. 85 W.; 200 miles; lat. 51·20, long. 28·7; strong breeze and overcast; heavy head-sea.

Monday, July 24.—Wind W. W. N. W.; course S. 89 W.; 185 miles; lat. 51·15, long. 33·13; fresh gale and high sea.

Tuesday, July 24.—Wind S. W. W. N. W.; course S. 77 W.; 273 miles; lat. 50·14, long. 40·7; fresh breeze and variable.

Wednesday, July 26.—Wind W.; course S. 68 W.; 265 miles; lat. 48·36, long. 46·24; moderate and foggy.

Thursday, July 27.—Wind westerly; course S. 66 W.; 293 miles; lat. 46·38, long. 53·3; moderate and foggy; 12·20 P. M. delivered despatches at Cape Race.

Friday, July 28.—Wind southerly; course S. 57 W.; 299 miles; lat. 43·56, long. 58·58; fresh breeze and dense fog.

Saturday, July 29.—Wind S. W.; course S. 69 W.; 291 miles; lat. 41·51, long. 64·56; light breeze.

Sunday, July 30.—Course S. 75 W.; 302 miles; lat. 40·32, long. 71·24; light breeze; 10 P. M. Sandy Hook; 10·50 Quarantine.

REMARKS.—Head winds retarded the vessel's progress very materially. Complete details of the construction of the *City of New York* will be found in the *Journal*, vol. xlvi, page 45. E. M. B.

On the Processes and Mechanical Appliances in the Manufacture of Polished Sheet Glass. By Mr. RICHARD PILKINGTON, Jr.

From Newton's London Journal of Arts, September, 1864.

The manufacture of British sheet glass was introduced into England about the year 1832, by Messrs. Chance Brothers, of Birmingham. Since then it has become generally used, having almost superseded crown glass, in consequence of the comparative ease of obtaining the large squares at present required for windows, and the absence of wave lines, by which the vision is so much distorted in crown glass. The average size of sheet glass is 40 inches by 30 inches, but, if required it can be made much larger, whilst with crown glass it is almost impossible to procure a square as large as 34 inches by 22 inches. Sheet glass, when used for windows, has generally a peculiar appear-

ance when viewed from the outside of a building, on account of the unevenness of its surface—an eyesore partially obviated by the improved method of flattening, but entirely removed when the glass is polished. When polished, it is known by the name of patent plate, to distinguish it from British plate. This polished sheet plate has a decided preference over British plate, being harder and more difficult to scratch, besides taking a higher polish. It is also cheaper.

The manufacture of polished sheet glass consists of the three following processes: 1st. Melting and blowing; 2d. Flattening; and 3d. Polishing.

1. *Melting and Blowing.*—Two furnaces are required, one for melting the materials or "frit," and the other for reheating the metal whilst blowing it into a cylindrical form. The melting furnace is a reverberatory furnace, arranged for maintaining a high temperature with great uniformity and freedom from dust or other impurities arising from the fuel. The furnace is fitted with pots, which are placed on a raised bed, extending the entire length of the furnace. The fire-grate also extends the entire length of the furnace, with the exception of a space of about 4 feet in length, and it is fed from the furnace. On each side of the fire-grate the pots are ranged, and a gathering or working hole is provided in the furnace wall for each pot. The air is supplied through an underground passage entering from the open air, and, by means of closely fitting doors, the draught is regulated with great nicety.

Formerly, it was considered necessary to use stone for the melting furnaces, but at the present time large bricks made of best fire-clay are preferred. A small fire is lighted upon the fire-grate and gradually increased, first to dry the furnace, and afterwards to bake it. Great care and attention are given to this operation, for upon it depends the duration of the furnace. After being baked, the furnace receives its number of pots, generally four or five on each side of the fire-grate, in all eight or ten pots.

The manufacture of these pots is a matter of special importance, and they are made of the very best Stourbridge fire-clay, which, when thoroughly tempered, is formed into rolls of about 1 lb. weight each, and worked, layer upon layer, into a solid mass, free from cavities containing air, and making a pot of about 4 feet height inside, 5 feet diameter at top, and about 4½ feet diameter at bottom inside, weighing when dried about 25 cwt., and containing about 22 cwt. of melted metal. Great care is requisite to prevent any particles of foreign matter from getting into the clay, for if that were to happen, the pot would not last its time, but would most likely give way when first heated to the working temperature. The average duration of a pot is about eight weeks, and their estimated value about £9 each. After being made, a pot remains in the same room for a year, the temperature being maintained at 60° Fahrenheit; and it is then removed to a warmer room, where it remains in a temperature of 90° until it is wanted. When required for use, it is taken to the "pot-arch" to be baked, where the heat is gradually increased to that of the melting

furnace, to which it is conveyed, whilst red-hot, as quickly as possible, by means of a carriage or a crowbar on wheels, and placed on one side of the fire-grate. This operation is repeated until all the pots are fixed in the melting furnace. The furnace ends are now closed, with the exception of the fire-hole at each end. A small portion of "cullet" or broken glass is put into each pot, and when melted is ladled so as to run down over the interior surface of each pot, after which the heat is increased for a short time. The pots are thereby glazed, and are now ready to receive the material to be melted.

The quantity of raw material or "frit" allotted to each pot is filled into it in three or four charges, allowing a sufficient interval of time to elapse between each charge to insure the previous one being melted. About sixteen hours of intense heat are required to melt the entire quantity, during which time the fluid metal boils violently, and before it can be worked requires cooling, which takes about eight hours. Whilst cooling, the small bubbles of air arising from the boiling of the metal ascend and pass away, leaving the metal clear, excepting the surface, which is coated with impurities from the frit, from the roof of the furnace, and from the dust of the fuel, all of which must be removed before commencing work. Inside each pot, and floating upon the surface of the metal, is an annular ring made of fire-clay, 2 inches thick, having an internal diameter of 18 inches. This inner space of 18 inches diameter is cleaned, instead of the entire surface of the metal, thereby saving both time and material. The cleaning or skiming is performed by means of a light iron rod, chisel-pointed, which, being warmed, the metal adheres to it; and this process is repeated whenever any impurities are perceived upon the surface of the metal.

The surface of the melted metal being cleaned, the workman dips into it a blow-pipe, having previously warmed the nose end of the pipe. Withdrawing 2 or 3 lbs. of the metal, he allows it to cool to a dull red, and then dips the pipe again, collecting by degrees in this way a sufficient quantity to produce a given sized sheet of glass, which, on the average, would weigh about 20 lbs. Then, while cooling the pipe, he continually turns it round, drawing it towards himself, and in so doing forces the metal beyond the nose end of the pipe, by means of a forked rest, in which the pipe revolves, leaving as little metal as possible upon the pipe. The blower now takes the pipe and places the red-hot mass in a hollowed wooden block upon the ground, keeping the pipe in a horizontal position whilst revolving it, thereby producing a solid cylindrical mass of metal. During this process, his assistant allows a fine stream of cold water to run into the block from a sponge, to keep the wood from being burnt, and give a brilliant surface to the glass. He next raises the pipe to an angle of about 75°, and blows until he has produced a hollow pear-shaped mass, with its largest diameter the same as that of the finished cylinder. During this operation, his assistant keeps the block wet, and a second block is generally used when commencing the blowing.

The glass now requires reheating, which is done at a furnace built of ordinary brickwork, in an oblong form, its dimensions being deter-

mined by the number of blowers intended to work at it,—generally four, five, or six at each side. The ground at each side of this furnace is excavated to a depth of about 7 feet, a width of about 16 feet, and the same length as the furnace, and over each of these spaces four, five, or six wooden stages are erected at distances of about 2 feet apart. Having reheated the glass, the blower repeatedly blows to maintain the cylinder of equal diameter throughout, whilst lengthening it by swinging it backwards and forwards in the 2 feet space, and occasionally swinging it round over his head, until a cylindrical piece of glass is produced, about 11 inches diameter, and about 50 inches long, closed at one end, and having the blow-pipe attached to the other end. The blower first opens the closed end as follows: Enclosing as much air as possible within the cylinder, and stopping the mouth-piece of the pipe with his hand, he exposes the end of the cylinder to the heat of the furnace, which, whilst softening the glass at the end, expands the contained air to such an extent that a small hole is burst in the glass. This hole is flashed open by revolving the pipe quickly, and, when flashed, the end of the cylinder is withdrawn out of the furnace; and by keeping the pipe in a vertical position for a few seconds, the metal cools sufficiently to keep its shape. The cylinder is then placed upon a wooden trestle, and by touching with a piece of cold iron the pear-shaped neck near the pipe nose, a crack is formed, which is continued round the neck by gently striking the blow-pipe, and thus the pipe is released.

The cylinder has now one end of full diameter, but the other is contracted to about 3 inches diameter, and must therefore be cut off. This is accomplished as follows: The cylinder having become cold whilst remaining on the trestle, the workman collects a small portion of metal upon the end of an iron rod, and draws it into a thread of glass about $\frac{1}{8}$-inch diameter, by means of a pair of pincers. This thread he passes round the body of the cylinder, and after it has remained on a few moments, the pincers, dipped in cold water, are applied to the heated part; and the sudden contraction causes the end to fly off with a sharp report, leaving the cylinder about 45 inches long and 11 inches diameter.

2. *Flattening.*—To produce a flat sheet of glass from the cylinder thus obtained forms the second process of the manufacture. The flattening is accomplished as follows: The end of the cylinder that was flashed being slightly contracted in diameter, and the thickness of metal much reduced, it is first necessary to cut off about 2 inches length from that end; for this purpose the cylinder is supported in a vertical position, by means of a cradle over a small horizontal table; the bottom edge of the cylinder is introduced between the jaws of a small cutting instrument, and the movable jaw, carrying the cutting diamond, is pressed by a spring against the interior surface of the cylinder; then by gently pushing the instrument forwards round the cylinder, allowing it to run freely upon its wheels, the end of the cylinder is cut off perfectly true. The cylinder then requires splitting longitudinally, which is accomplished by placing it in a horizontal position in a wooden cradle; and a diamond fixed in the cleft of a stick is drawn along in-

side the cylinder from end to end, guided by the straight edge—a gentle pressure being exerted on the glass in opposite directions, at the diamond cut, to complete the splitting.

The cylinder is now taken to the flattening kiln, which consists of two furnaces built together,—the first for flattening, and the other for annealing; the former being maintained at a much higher temperature than the latter. A portion of the bottom of the flattening kiln, slightly larger than the largest sheet of glass to be flattened, is supported upon a carriage, which, with the flattened sheet, is made to travel into the annealing kiln, this plan being a very great improvement over the old method of pushing the flattened sheet whilst in a soft state. The movable bed is either of clay or stone, and by careful work is made as true as possible; upon this a sheet of glass is first flattened and left there to flatten others upon, in order to obtain sheet glass with as true a surface as possible. The split cylinder to be flattened is gradually introduced into the flattening kiln, and when sufficiently warmed is placed upon the glass bed with its split side uppermost. The heat soon softens it, so that, with a slight assistance from the workmen, it lies down nearly flat on the bed, and the sheet is afterwards rubbed as flat as possible with a piece of wood fixed to the end of an iron rod. The movable bed is now pushed forwards into the annealing kiln, and after placing another cylinder to warm, the workman removes the flattened sheet from the carriage by means of a tool like a fork, and places it upon a prepared part of the floor of the annealing kiln to stiffen previous to piling it. The carriage is now returned to the flattening kiln, and the flattening operation repeated, till the carriage again appears in the annealing kiln. The previously flattened sheet is first piled on its end against one side of the kiln, and then the last flattened sheet is removed off the carriage, and left to cool on the floor of the annealing kiln like the previous sheet. This flattening process is continued until the annealing kiln is filled, when it is closed up and allowed to cool, generally from 24 to 36 hours, the time being regulated by the thickness of the glass. On the completion of the cooling, the kiln is opened, and the sheets of glass are taken to the warehouse, where they are sorted to suit various purposes, a very large proportion being packed and sent away without undergoing any further process.

3. *Polishing.*—The sheets intended to be polished are now selected, and pass through the third process of manufacture, to produce polished sheet plate. Two processes are necessary for this purpose—smoothing and polishing.

Smoothing consists in working two sheets of glass, one upon the other, by hand, with emery and water between them; and as their surfaces become obscured, finer and finer emery is used, until the surfaces are smoothed free from all defects. The apparatus used consists of a wooden bench, one half of which is 6 inches higher than the other; upon the former is placed a slab of slate, about 1½ inch thick, larger than the sheet of glass, having as true a surface as possible. Upon this slab a sheet of glass is laid, with a piece of wet calico between the surfaces of the glass and the slab. By exerting a gentle pressure upon the

glass, the air is expelled from between them, and the sheet of glass is consequently held down upon the slab by the whole atmospheric pressure upon its surface, which holds it so firmly that when the sheets have to be raised from the slab, many are broken, even by experienced workmen. The wet calico is used in this case instead of plaster of Paris, for bedding the sheet of glass upon the table. In consequence of the close adhesion caused by the atmospheric pressure when the surfaces of the two sheets of glass get so true as to become closely in contact, it is impossible to work two large sheets, one upon the other, with the finest emeries, and it therefore becomes necessary to perform the latter portion of the rubbing process with a small piece of glass, say about 10 inches by 5 inches, until the process is completed. Both sides of the sheet of glass having been smoothed in this manner, and, after a careful examination, found free from defect, the sheet is then handed over to the polishing machine.

The perfection of the smoothing process is entirely dependent upon the purity of the emery, and the perfect uniformity of the grain in each successive quality employed; and consequently a very perfect process of cleansing and sorting the emery is requisite. The ordinary ground emery contains, besides numerous degrees of fineness of grain, many impurities which must be removed; and the good emery must also be accurately sorted into portions varying in size of grain from coarse to the finest. For every degree of fineness a separating vessel or cylinder is required; and, taking No. 1 as the coarsest quality, that cylinder is made the smallest in the series, No. 2 cylinder about twice the capacity of No. 1, and No. 3 twice the capacity of No. 2, and so on throughout the required number of cylinders. The emery sorting apparatus consists of the required number of cylinders fixed so that No. 1 cylinder is about 3 inches higher than No. 2, and No. 2 the same height above No. 3, and so on. The cylinders are made of copper, and inside each is fixed a copper funnel, long enough to reach within 3 or 4 inches of the bottom of the cylinder; and in the bottom of the cylinder is a hole, closed by a wooden plug or valve of about 3 or 4 inches diameter, which is held up by a rod and spring balance. The action of the apparatus is as follows: A supply of water being maintained by the cistern, a constant stream is delivered, by means of a tap, into the funnel of No. 1 cylinder. The water descends through this funnel to the bottom, and ascends through the annular space to the top of the cylinder, whence it is conveyed by a spout to the funnel of No. 2 cylinder, ascending in the annular space of No. 2, and passing by a spout to No. 3 funnel. This is repeated as often as there are cylinders; and from the last and largest cylinder the overflow is carried to a drain. When the stream of water is running through all the cylinders and also passing away at the overflow, the powdered emery to be cleansed and sorted is sprinkled into the funnel of No. 1 cylinder, and this is continued until enough has been fed to fill up to within $\frac{1}{2}$-inch of the bottom of the funnel. No. 1 being the smallest cylinder, the current of water through it will be the fastest, and the grains of emery left behind in this cylinder will consequently be the coarsest. The feeding of the

emery is then stopped for a short time, and the stream allowed to continue until the water is running quite clear into the funnel of No. 2 cylinder. A valve at the bottom of No. 1 cylinder is now opened, allowing the emery and water to fall into a vessel placed beneath to receive it; and as soon as the stream of water is again running through all the cylinders, and passing away at the overflow, more emery is again sprinkled into No. 1 funnel. The succeeding cylinders are emptied in the same way, as they respectively become filled with the finer sorts of emery. The beauty of this process is the simplicity of the apparatus required, and the certainty of always obtaining an exact repetition of the several degrees of fineness in the respective cylinders. It will be observed, that, in consequence of the cylinders increasing successively in capacity, the current of water ascending in the annular spaces decreases in velocity in the same proportion; consequently the emery deposited in each successive cylinder increases in fineness over that deposited in the previous one.

For the final process of polishing the sheets of glass after smoothing, the machine used is the same as that described at a previous meeting for polishing plate glass. The polishing benches have two bars, carrying the polishing blocks, and working lengthways, backwards and forwards, over the table on which the sheet of glass is laid, which is made to travel alternately from side to side transvesely to the bars. The polishing blocks are worked at about sixty double strokes per minute, and the bars carrying them are supported upon rollers at a height of 6 or 8 inches above the table. The moving table is worked similarly to the table of a planing machine, moving one way quicker than the other, by a reversing motion, similar to that of a planing machine bed.

It is generally considered that, to obtain a good polished surface, the polishing blocks should not pass twice in succession over the same surface. Upon the moving table are fastened slabs, made of a wooden frame, covered with slates, upon which the sheets of glass to be polished are bedded in plaster of Paris. After one side has been polished, the glass is taken up and relaid, and the other side polished. The polishing blocks are about 5 inches square, covered with felt, and weighted with about 84 lbs. each. The red liquor used is polishing is red oxide of iron, obtained by burning sulphate of iron in a reverberatory furnace to a dark red when cold, and it is then ground in water to the finest grain possible. The cutting grain of this material is about the hardest and finest that can be produced, and well worth examination by the microscope.

Mr. Pilkington exhibited a series of specimens from the St. Helen's Crown Sheet and Plate Glass Works, illustrating the several stages of the manufacture, and the materials employed.

The chairman observed that the members had had an opportunity, on the occasion of the Liverpool meeting, of seeing the manufacture of plate glass at the Ravenhead Works, and a paper on the subject had been read on that occasion; and the present paper gave a corresponding description of the manufacture of polished sheet glass.

Mr. P. Rigby observed that polished sheet glass was a very superior

article to the crown glass of which it had taken the place, and required more care in the final polishing process, in order to get both sides of the glass finished to the same degree of polish. Much depended upon the correct separation of the emery powder into proper gradations of fineness, which was effected by the successive cylinders in the emery washing apparatus being made in correctly-adjusted progression, as regarded their size. Great care was also needed in feeding the emery powder into the first funnel, so as not to go on feeding too long, otherwise some of the coarser particles would get carried over by the current of water into the next cylinder, along with the finer sorts. The time of polishing the sheets of glass was generally required, in his own experience at Messrs. Chance's works, to be longer for the side first polished; because when the plate was turned over for polishing the second side, the first surface became slightly dulled by being laid in the plaster; and he inquired whether, in the specimens exhibited of polished glass, the time of polishing had been equal for both sides, or longer for the first side.

Mr. Pilkington replied, that it took about nine hours on an average to polish each side of a sheet of glass, but there was no fixed time for the process, the polishing being continued until the surface of the glass was brought up to the requisite brightness; and he had not found that it afterwards became dulled at all by being laid in the plaster for polishing the other side, the plaster having no sensible effect on the brightness of the surface. Even in what was called the rough state, however, before smoothing or polishing, sheet glass was quite equal in appearance to ordinary crown glass; while the finest and thinnest sort of polished glass of which a sample was shown, was that made for the use of photographers, and for framing fine engravings. The emery sorting apparatus was found in practice to divide the different sizes of emery with extreme accuracy into the respective cylinders, as was proved by examining with a microscope the several degrees of fineness.

Mr. J. E. Clift inquired whether the rubbers had to be moved at intervals during the polishing process, in order to examine the surface of the glass.

Mr. Pilkington replied, that was not necessary, as the rubber traveled far enough at each stroke to expose the whole surface to view; and the workman examined the degree of polish of the surface, by holding a lighted candle near it while the glass was still lying on the slab of the machine. The process was stopped as soon as the glass appeared sufficiently polished.

Mr. F. J. Bramwell observed, that if it were the fact that the surface of the glass became at all dulled by being laid in plaster, and if it were attempted to compensate for this by polishing the first side longer than the second, the result must be that both sides would be defective in polishing, the second side not being finished to a greater degree of polish than the first side would have after lying in the plaster. The smoothing and polishing processes here employed were indeed identical with those in the manufacture of plate glass; but the latter required a preliminary process of grinding, on account of the unevenness of its

surface on leaving the annealing oven, whereas the blown sheet glass had its surface sufficiently even to allow of its being laid at once on the smoothing machine, without having undergone grinding. The emery sorting apparatus was the same that was used in plate glass machinery, and he did not think a more perfect plan could be devised for separating the several degrees of fineness. The principle was as simple as possible, the different sized particles being accurately sorted according to the velocity of the current of water in the successive cylinders, just in the same manner as a river discharging itself into a lake, deposited the heavier portions of its detritus at the entrance, and carried the lighter matters further out into the body of the lake. A similar method had formerly been employed in the preparation of beaver for the manufacture of hats, the hairs being separated from the beaver by a current of wind just sufficient to float the beaver; this accordingly deposited the hairs at a near point, but carried the beaver to a greater distance. In grinding the emery, the old plan had been to grind it dry under edge runners, and as there was no provision for removing the particles as fast as they were ground, the consequence had been that some portions were overground, and impeded the grinding action of the machine upon the portions that still required grinding. Now, however, by grinding the emery wet, with a stream of water constantly carrying off the particles as soon as they were ground, the machine was kept continually cleared, and was enabled to grind in two days as much emery as it had previously ground in six. The principle of the stream of water was the same as that of the air blast used in mill-stones to remove the flour from between them, and in the American rice-husking machines for blowing away the husk of rice grains as soon as it was broken up fine enough to be so removed.

The Chairman inquired whether any improved mode of laying and lifting the plates of glass on the machines had been devised, in order to diminish the risk of breaking the glass. He thought there seemed room for improvement in that respect, for at present the loss by breakage of the glass in handling was very great.

Mr. Pilkington was not aware of any improvement having been made in that respect, though it was certainly much needed.

Mr. E. A. Cowper observed, that for smoothing the sheets of glass, instead of the process being performed by hand, as described in the paper, a machine was employed at Messrs. Chance's works, in which the smoothing action was produced by a link motion, like the parallel motion of beam engines, the upper sheet of glass not working right round upon the lower, but passing over it in a curvilinear course, with a figure of 8 movement. The melting furnace employed appeared to be the ordinary form of furnace used for glass melting, previous to the introduction of Mr. Siemen's regenerative gas furnace. In the construction of the old furnace, one practical difficulty arose from the "tears" or droppings of dirt from the brickwork forming the roof of the furnace, which dropped into the glass melting pots, and damaged the glass; this was now obviated by setting the lower rows of bricks each a little in advance of the upper, so as to present a slight step in-

side the furnace, which prevented the "tears" from dropping, and caused them to run down the sides of the furnace instead. The use of a current of air for separating fine substances, to which reference had been made, was also adopted in the process of grinding sulphur for vulcanizing purposes.

Mr. P. Rigby remarked, that the smoothing machine used at Messrs. Chance's works had been adopted for giving the smoothness of polished plate glass to sheet glass, as that was now required for many purposes, and particularly by photographers; but hand smoothing never made the surface quite so smooth and uniform as was done by the machine.

Pro. Mech. Eng. Soc.

New Green Pigment.

From the London Chemical News, No. 281.

Under the name of "Green Cinnabar," Vogel describes a new color which is prepared in the following way: Prussian blue is dissolved in oxalic acid; chromate of potash is added to this solution, which is then precipitated with acetate of lead. The precipitate, well washed, dried, and levigated gives a beautiful green powder. By varying the proportions of the three solutions, various shades of green may be procured. Chloride of barium or nitrate of bismuth may be used in place of sugar of lead.—*Chem. Central Blatt.* [Another mode of preparing this color will be found at page 182, vol. ix, *Chem. News.*]

The Strength of Cast Iron Water Pipes.

From the London Mechanics' Magazine, November, 1864.

Before the introduction of cast iron, water pipes were made in England of fig tree wood, and straight pipes, from twelve to twenty feet in length, were bored out of this material. Such pipes are now very scarce here, but we have seen many in use for even rather large mining pumps in eastern Europe. Wooden pipes can be made from one and a half to eight inches in the bore, which is generally one-third of the diameter of the pipe. The joints are, of course, upon the spigot and socket plan. Cast iron has now superseded wood for this purpose almost everywhere, although the introduction of such a strange material as tarred pasteboard is now being attempted for water pipes. The insides of cast iron pipes are generally varnished, or are sometimes covered with hydraulic cement in order to protect them from oxidation.

It will be seen that the strength of the metal depends upon the pressure of the water and the diameter of the pipe. The thickness of a cast iron water pipe is never so great as to bring into play those peculiar conditions of tensions which exist, for instance, in the cylinders of hydraulic presses or of ordnance. A water pipe is simply strained like the comparatively thin cylindrical shell of a boiler, or of a steam pipe. A cylinder undergoing an interior pressure, which tends to either increase its diameter or to burst it, while the section of the metal is of equal thickness throughout, is a sufficiently simple

case. The interior pressure tends to split the pipe longitudinally in a plane passing through the axis of the cylinder. The pressure exercised on any given length of piping is clearly equal to the product of the pressure per any given unity of surface, say per square inch, into the area of a rectangle, the height of which is the interior diameter of the pipe, while its length or base is equal to the length of the pipe itself. The total pressure is thus the fluid pressure multiplied by the interior diameter and by the length of the pipe. The surface of metal which resists this tension is equal to the external diameter *minus* the internal diameter multiplied by the length of the pipe, or twice the thickness of metal multiplied by the length. There will, therefore, be equilibrium between the force which tends to produce rupture and the resistance if the product of the coefficient of rupture of the metal, with the difference of the inside and outside diameters, be equal to the internal tension. This would be the bursting tension, which is, for cast iron, about 16,500 pounds per square inch. The working tension is usually one-sixth of this, or 2,750 pounds per square inch, while the proof tension, or the pressure at which the pipes ought to be tested, is twice the working tension. It is clear on reflection that the resistance of pipes of internal tension is quite independent of their length. As the length increases, so does the metal which has to resist the increased pressure due to additional length also increase in the same direction. Mr. Fairbairn has given the results of two experiments on leaden pipes, which show that the resistance of pipes to internal tension is independent of length. He has also made similar experiments in tubes of plate riveted together, and of different lengths. The results were very irregular, and did not demonstrate much beyond the fact that rupture always took place at the riveting.

Such is, of course, the theoretical strength of water pipes; but there is a great difference between a calculation of theoretical strength and the necessary regard to the complicated requirements of practice. When all the different points influencing the behaviour of even such an apparently simple thing as a water pipe are taken into consideration, some excuse is found for existing empiricism. On the other hand, the really practical man is he who neither neglects, nor is ignorant of the sublime teachings of science on the one hand, nor common sense requirements on the other. Amongst the practical conditions which are not to be met here by calculation, may be reckoned accidents in fitting in pipes, and the consequent external strength they ought to have in order to resist without fracture any sudden blow or accidental pressure from the outside. Another very important reason why such pipes should have a strength and thickness beyond that which would be due to the pressure of the water, is their liability to shocks caused by sudden stoppages of the current of water, and producing effects similar to those in the machine called Montgolfier's hydraulic ram. The danger is all the greater, as the speed is greater, and inferior granular cast iron often sweats under this action, even if the metal does not entirely give way. These dangers are necessarily diminished if the cocks and valves are so arranged as to close gradually. Another very important

effect on the strength of a pipe would be any inequality in its shape, equivalent to a serious departure from a true hollow cylinder. Fluid pressure, acting in all directions, continually strives to produce a perfectly cylindrical pipe, and thus the material of a tube which is not perfectly cylindrical, is injuriously strained in an unexpected way by this action. For these reasons, in fixing the strength of gas and water pipes, a constant thickness is added to that which is determined, in order to merely resist the interior pressure. Of very great influence is, of course, the quality of the metal, as the range in quality of cast irons is very great. The mode of casting is also of very great effect. A cast iron bar cast vertically is often nearly one-third as strong again as a bar cast horizontally, and pipes cast vertically are much superior to those cast horizontally.

For many years the engineers of the water works of Paris used the formula: $E = 0^m{\cdot}00238n\,D'' + 0\cdot0085$; in which E is the thickness of the pipe, n is the number of atmospheres of pressure per square metre, which has to be supported by the tube, D″ is the inside diameter, the numbers being given in metres. This would correspond to an ultimate resistance of 2,170,000 kilogrammes per square metre. Morin states that the improvement of late years in the quality of cast iron, and the plan of casting the pipes vertically have allowed these thicknesses to be somewhat reduced. The present formula is: $E = 0^m{\cdot}0016n\,D'' + 0^m{\cdot}0080$, in which the resistance to rupture of the cast iron is taken at higher value of 3,000,000 kilogrammes, while the pressure is taken as equal to 10 atmospheres. The formula is thus brought to: $E = 0^m{\cdot}016\,D + 0^m{\cdot}008$. In the few cases where great strength is required, with a larger diameter than usual, it is probable that the principle of shrinking rings on the outside of cylinders intended to withstand great pressures, might be occasionally adopted in the case of large water pipes, at least to a limited extent. Careful cooling from the inside, as with Rodman's guns, would also produce a stronger tube.

The best and most solid joint for any pipe is a flange joint, and the only reason for its non-adoption in any particular case is, that other joints—such as the common socket joint—are cheaper. Of course, the flange joint, however good and strong, is but little used in any great length of tubes, on account of its great expense. With a long length of pipes, compensation joints have to be adopted, in order to take up the effects of expansion and contraction of the metal, caused through the alterations of temperature. The expansion of cast iron is 0·0000111 for every degree Centigrade of heat, and the difference of the lowest temperature in winter to the highest in summer being nearly 50° C., this amount of expansion has to be multiplied fifty times. A joint of this kind is generally put down at every three hundred feet of length. The most disastrous effect, however, on any pipe is that of frost, and no winter passes by without our hearing complaints on this matter, and without noticing letters from indignant correspondents in our own columns and those of the daily papers. The bursting effect of frost is probably practically irresistible. A bomb-shell, if filled with water, the hole for the fuze being closed by a screw, is easily burst by the

expansion of the water inside while freezing. Gunpowder exerts a pressure of some 30,000 lbs. per square inch, so that the force of expansion of the freezing water is at least equal to this amount. For reasons which we have not yet heard sufficiently explained, water may be at freezing point, but if kept flowing will not freeze. The slight internal friction of the water itself, and more especially its friction against the sides of the pipe, probably develop a certain amount of heat. At the same time, the mere fact of the flow keeps the pipes clear, and can be supposed to drive any ice, which might be even on the brink of formation, out of the pipe. It is probable that in our own comparatively mild climate, the freezing and consequent bursting of pipes in winter are oftener due to the bad nature of the material than to temperature alone. The water is taken up by capillary attraction into the porous sides, and having soaked itself in, it expands with irresistible force within the spongy mass, driving it asunder. We here see the very great necessity for testing the pipes by hydraulic pressure, more especially if they be cast horizontally. The theoretical strength and the practical strength required are easily calculated, but no reckoning could take into account the effects of bad material or bad casting. As we have observed, the proof tension should be twice the working tension, which is itself generally made one-sixth of the ultimate strength of the pipe, or that tension at which it should burst.

In the designing of a series of water mains, there is a great field for the display of science and the production of economy of material and working power. Sudden bends and knee pipes should be entirely avoided, and curved pipes should be used with as large a curvature as possible. Sudden changes in the diameter are also to be prevented, and the passage from one diameter to another should take place as gradually as possible. The gain is of a double kind. In the first place, obstructions to the flow cause shocks, which either require great strength in the pipes themselves, or end by breaking them up. In the next place, such obstructions cause great losses in useful effect, which have to be paid for in some way—in the extra engine power, for instance. There can be no doubt, again, that there is one point with regard to water pipes which is still to a great extent ignored by most practical hydraulicians. We mean as to the effect of the state of the surface on the flow, and also as to the influence of the diameter. A large number of experiments which have been lately made in France would seem to point to this, and we lately took occasion to allude to their importance.

On the Supposed Nature of Air prior to the Discovery of Oxygen.

By GEORGE F. RODWELL, F.C.S.

Continued from vol. xlix, page 406.

From the London Chemical News, No. 272.

In Obs. 16 "Of Charcoal or Burnt Vegetables," Hooke propounds his celebrated theory of combustion, a most philosophical and ingenious theory, and far in advance of the chemical knowledge of the day.

From very ancient times fire was believed to be an element more

divine than air, water, and earth, and to occupy a place above them. We find this theory in the most ancient Vedas, in the Zend Avesta, and in the writings of Sanchoniatho; indeed, we know that fire was the divinity of the Zoroastrians, and first invoked among the deities of the ancient Hindus, was Agni, the god of light and fire. Fire was universally believed to be an element till the time of Bacon, and almost universally for many years afterwards. Bacon,* in his investigation of the nature of heat, denies that it is elemental, and states his belief that it is "merely compounded of the conjunction of heat and light in any body;" heat, he elsewhere affirms, is a violent motion of the smallest particles of bodies, and heat can produce light, hence he completely destroyed the elemental nature of fire. Hooke went much further than this, for his theory affirmed:

1. That the air is the "universal dissolvent of all sulphureous bodies."

2. That the dissolution does not commence until the body to be dissolved has been heated to a certain temperature.

3. That the process of dissolution generates that which we call *fire.*

4. That the process of dissolution is performed with such intense violence that it agitates the smallest particles of the combustible matter, with sufficient rapidity to generate "the action or pulse of light."

5. That the solution of sulphureous bodies is made by "a substance inherent and mixed with the air, which is like, if not the very same, with that which is fixed in saltpetre."

6. That in the process of dissolution, a part of the combustible body is turned into air, and caused to move with it.

7. That in the process of dissolution, a part of the combustible body is not turned into air, but is carried up by the motion of the hot air, and when the heat ceases, descends again, and this part is a certain kind of salt found in soot.

8. That in the process of dissolution, certain bodies capable of being dissolved are carried upwards, and do not suffer dissolution, because the motion of the surrounding air does not allow them to remain sufficiently long in a heat competent to cause them to be acted upon by the air, and this is the combustible part of soot.

9. That there are parts of the combustible body which cannot be dissolved by the air, and are not sufficiently light to be carried upwards by the motion of the hot air, and this constitutes the ash of burnt bodies.

10. That "the dissolving parts of the air are but few," they soon become satiated, and the combustible body then ceases to be acted upon, until it is supplied with a fresh quantity of air; but in saltpetre the dissolving particles abound in great quantity; hence this body is able, when melted, to rapidly dissolve a large quantity of a combustible body.

11. That, as with liquid solvents, if we repeatedly add fresh quantities of a weak solvent, the body to be dissolved disappears as quickly as if a strong solvent be added all at once, so if we apply fresh quantities

* "Nov. Org.," Book 2, Aph. 20.

of air repeatedly, as by bellows, to a body undergoing combustion, it suffers solution as quickly as when it is placed in melted nitre.

12. That there is no such thing as an "element of fire," for the "shining transient body, which we call flame, is nothing else but a mixture of air and the combustible volatile parts of any body, which parts the encompassing air does dissolve or work upon."

This theory had been worked out by Hooke several years earlier, and was well supported by experimental facts; it is much to be regretted that he does not give any of the experiments, neither has he, in any future publication, enlarged or developed the theory, although he states that he has here "only time to hint an hypothesis, which, if God permit me life and opportunity, I may elsewhere prosecute, improve, and publish." Assuredly if he had adduced experiments in support of his assertions, the theory of four elements would now have been annihilated; but this earliest amongst the physical conceptions of the human intellect, was not yet destined to receive its death-blow; that which had dwelt so long in the human mind, had taken such a deep root therein, had endured uninjured, through the greatest changes of intellectual development, the greatest changes in the tone and mode of thought, had seen the downfall of old systems of philosophy, and the rise of new ones, could not so easily be displaced from the minds of men. Many years must pass; experiments must be accumulated; chemistry must free itself from empiricism and become a science; the Phlogistic theory must arise, and be vanquished by Lavoisier, before that change can take place.

In the 58th observation of the "Micrographia" Hooke treats "of a new property of the air." It is constantly observed, he writes, that the sun and moon, when near the horizon, have their images distorted, and assume a red color; moreover, trees and other objects are sometimes observed to possess an unsteady appearance at sunset; these effects he attributes to the "inflection or multiplicate refraction of those rays of light within the body of the atmosphere." That the refractive power diminishes with its rarefaction, Hooke proved by viewing an object through a hollow glass sphere, containing much rarefied air, and then admitting air; the object was viewed through an aperture placed in front of the sphere, of such a size that every part of the object was just included in the field of view; on now admitting air to the interior of the sphere, a part only of the object was visible.

We know that the air is less dense the further it is from the surface of the earth, from the fact that the mercury column sinks in a barometer as we ascend a mountain; and, he continues, the law regulating the descent of the mercury may be illustrated by "a means which somewhile since I thought of and used, for the finding by what degrees the air passes from such a state of density to such a degree of rarity." He next details a number of experiments—made with precisely the same apparatus as that employed by Boyle—which prove conclusively that the volume of air varies inversely as the pressure to which the air is submitted.

It is remarkable that Hooke does not mention Boyle's name in connexion with the law, although in the "Defence against Linus," published more than two years previously, Boyle (as we have seen in a former paper) gives a number of experiments clearly proving the law; moreover, he had described his experiments at several meetings of the Royal Society in the presence of Hooke. We cannot imagine that Hooke wished to give Boyle less than his due, for he constantly mentions suggestions which he received from him, and always speaks of him in the highest terms. In the preface of the "Micrographia" he speaks of "the most illustrious Mr. Boyle, whom it becomes me to mention with all honor, not only as my particular patron, but as the patron of philosophy itself." Again, he speaks of "the incomparable Mr. Boyle." It is also remarkable that Boyle does not mention Hooke's name in connexion with the law, for the former is always most ready to acknowledge the discoveries and inventions of others. It is impossible to say who first verified the law; at all events, Boyle was the first to suggest that the experiments should be made, and to describe a method for making them. Hooke speaks of his own experiments as *confirming* the law, not as giving rise to it; indeed, both he and Boyle attribute the idea that "the pressures and expansions are in reciprocal proportions" to a Mr. Richard Townley. We must remember that at the time of the discovery of the law, the air was the only gaseous body known, and a law which had been proved to apply to one body, would obviously be considered of a less importance than one which applied to a whole class of bodies. It is to this that we must attribute the fact that no trouble was taken to ascertain the true history of the law by those writers who lived at the time of its discovery.

The history of the law, as far as I have been able to trace it, seems to be the following:

1660.—Boyle, in his "Physico-Mechanical Experiments," suggests a method for determining the relation of the density of air to the height of the column of mercury which it supports.

Townley, after reading Boyle's suggestion, makes some experiments on the subject, which induce him to propound the theory that "the pressures and expansions are in reciprocal proportions."

Hooke, not having heard of Townley's theory, makes some experiments, but without finding that "the pressures and expansions are in reciprocal proportions."

Mr. Croune and Lord Brouncker make some experiments on the subject.

1661, (August 2.)—Hooke, having heard of Townley's theory, makes some further experiments by a different method, which confirm it.

September 11.—Croune gives an account of his experiments on the subject before the Royal Society.

Boyle, at the same meeting of the Society, describes some experiments previously made, which confirm the theory.

1662.—Boyle in his "Defence against Linus," publishes a detailed account of the experiments described before the Royal Society in the

previous year, and affirms that "an accurate experiment of this nature . . . has not yet been made (that I know) by any man."

1665.—Hooke publishes in detail the experiments made on August 2, 1661.

1676.—Mariotte, in his "Essai sur la Nature de l'Air," publishes some experiments made by himself and a M. Hubin, which confirm the law.

I must still adhere to the opinion expressed in a former paper, that the law which affirms that the volume of a gas varies inversely as the pressure to which the gas is submitted, is rightly "the law of Boyle."

Hooke, not only by his writings, but by inventing and improving many philosophical instruments, eminently benefited experimental science. Now that the old philosophy was to be expelled from the minds of men, now that Nature was no longer to be interrogated by the unaided senses, it was necessary that there should be instruments to assist the inquirer. Hooke was the very man that was wanted at the time; a good mathematician, possessing admirable inventive faculty, and a patient experimenter. He was a greater mechanical genius than Boyle, but I will not say a more ardent experimenter. Both were worthy to put in practice the tenets of the new philosophy; both were true types of the Baconian philosopher; their names will never disappear from the annals of science, will never cease to be reverenced by all true students of Nature.

(To be continued.)

The Coal Mines of the World.

From the Journal of the Society of Arts, No. 657.

M. A. Burat, in a work entitled *Situation de l'Industrie Houllière en* 1864, gives the following as the statistics of the extent of known coal fields and their annual production:

	Extent in hectares, (1 hectare being equal 2·471 acres.)	Tons.
British Isles, . . .	1,570,000	86,000,000
France, ...	350,000	10,000,000
Belgium, ...	150,000	10,000,000
Prussia and Saxony, . .	300,000	12,000,000
Austria and Bohemia, . .	120,000	2,500,000
Spain, ...	150,000	400,000
North America, . . .	30,000,000	20,000,000
Total, . . .	32,640,000	140,900,000

As regards France, the coal basin of the Loire, which is only 25,000 hectares in extent, furnishes three-tenths of the whole of the coal raised in the country.

Improvement in the Giffard Injector. By M. TURCK.

As this instrument was originally constructed, the cylinder which receives the steam, its nozzle, and the needle which occupies its axis, slid together in the enveloping jacket when it was necessary to change the opening of the annular orifice by which the feed-water mixes with the steam. This arrangement requires two stuffing boxes. M. Turck removes these boxes, and renders the cylinder, nozzle, and needles fixed, and avoids the contact of the cold water with the wall of the steam-nozzle, by interposing between the cylinder which receives the steam and the jacket a metallic piece surrounding the cylinder and its nozzle. This envelope alone is movable, and by its longitudinal motion closes or opens the annular space by which the feed-water enters. The Committee of the *Society for the Encouragement of National Industry* approve of the change and publish the specification and drawing.

Coloration of Glass.

M. Pelouze having observed that the glasses of commerce were colored yellow by carbon, sulphur, silicon, boron, phosphorus, aluminum, and even by hydrogen, was lead to make a series of experiments for the purpose of ascertaining the cause of the identity of the results with such different reagents. The conclusions which he has reached, and which his experiments place beyond doubt, have a very considerable importance in reference to the possible perfection of our manufactures of glass. In fact, his first conclusion is that "all the glasses of commerce contain sulphates." These salts (sulphates of soda, potassa, or lime) render the glass more or less alterable by atmospheric agency, and come into the glass from two sources, either directly from the use of these sulphates as a flux, or from the presence of the sulphate of soda as an impurity in the commercial carbonate. The effect of their existence may be seen by examining many of the panes of glass in our windows, which have been for some years exposed to the air, when the surface of the glass will be found to be corroded and partially opaque like ground glass, and by examination under a magnifier will be found to be covered with crystals. M. Pelouze found these sulphates present from one to three per cent. in all the commercial glasses, window, plate, table, bottle and Bohemian glass: he also found two per cent. of sulphate of soda in a glass from Pompeii. The coloration is now easily explained, the reagents named above reduce the sulphates and produce an alkaline sulphuret which has the property of giving the yellow color.

M. Pelouze proved his proposition by showing, first, that when the glass materials were carefully purified from sulphates, no color was produced by carbon, hydrogen, boron, silicon, phosphorus, or aluminium; and, secondly, that an alkaline sulphuret added to the pure materials produced the color.—*Acad. Sciences of Paris.*